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WEATHER BUREAU

CHARLES F. MARVIN, Chief

MONTHLY WEATHER REVIEW

VOLUME 48, No. 8

AUGUST, 1920

WASHINGTON
GOVERNMENT PRINTING OFFICE
1920

INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological contributions, and bibliography including seismology; (2) an interpretative summary and charts of the weather of the month in the United States and on the adjacent oceans; and (3) climatological and seismological tables, dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (*a*) Results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; (*b*) abstracts or reviews of important meteorological papers and books; and (*c*) notes. In each issue of the REVIEW reviews, abstracts, and notes are grouped by subjects, roughly, in the following order: General work, observations, and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture weather; applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but **the publication of contributions is not to be construed as official approval of the views expressed.**

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. *Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U. S. Weather Bureau, Washington, D. C.,"* in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW OR SUPPLEMENTS.

The section of the weather of the month contains (1) an interpretative discussions of the weather of North America and adjacent oceans and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
Meteorological and Seismological Service of Mexico.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

SUPPLEMENTS, containing kite observations, and others containing monographs or specialized groups of papers, are published from time to time.

NOTES TO CONTRIBUTORS.

Authors are requested to accompany their papers submitted for publication with a brief opening synopsis. When an article deals with more than one subject—as, for example, a method of measurement, some experimental results and a theory—each subject should be summarized in a *separate paragraph*, with a title which clearly describes it.

When illustrations accompany an article submitted for publication in the MONTHLY WEATHER REVIEW, the places where they should appear in the text should be indicated, and legends or titles for them should be inserted just after the end of the article. As far as practicable the illustrations when accompanied by their legends should be self-explanatory—i. e., the data on them should leave no doubt of what they are intended to convey.

BACK NUMBERS OF THE REVIEW WANTED.

The Weather Bureau has not enough of the following numbers of the MONTHLY WEATHER REVIEW to meet even urgent requests for filling up files at institutions where the REVIEW is constantly being referred to. The return of any of these or of any 1919 or 1920 issues, especially November, 1919, will be greatly appreciated. The attached addressed franked slip may be used for this purpose, or one may be had on application to the Chief, U. S. Weather Bureau, Washington, D. C.

1914: January, February, March, April, September, October, December.
1915: May, June, July, August.
1916: January, August.
1917: June.
1918: February, September.
1919: Any issue, especially November.
1920: Any issue, especially January.
SUPPLEMENT, No. 3.

MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

VOL. 48, NO. 8.
W. B. NO. 717.

AUGUST, 1920.

CLOSED OCT. 4, 1920
ISSUED OCT. 28, 1920

MATHEMATICAL INQUIRY INTO THE EFFECT OF WEATHER ON CORN YIELD IN THE EIGHT CORN BELT STATES.

By H. A. WALLACE, Associate Editor of *Wallace's Farmer*.

INTRODUCTORY NOTE.

Within the past few years a number of mathematical studies have been published regarding the effect of weather on crops. Prof. J. Warren Smith, Mr T. A. Blair, Mr. J. B. Kincer, Mr. J. Cecil Alter, Prof. H. L. Moore and others have drawn attention to the great importance of utilizing statistical methods for the formulation of relations between the occurrence of certain agricultural, meteorological, or other phenomena, with alleged controlling factors. These are evidences of the advancement of the science of meteorology from the purely empirical stage to a more scientific one in which mathematical methods are employed to state relations rather than indefinite words and language.

The criticism is sometimes made that results of the statistical analysis are necessarily crude and inexact, and that large deviations from the theory are met with. This may be true, but it is capable of improvement will come with more advanced studies.

It is also alleged that capable students are able to do quite as well without the aid of the mathematical formulæ. This may be true, but the statistical data to prove it so have by no means been advanced; in fact, they are perhaps not available. Moreover, it must be recognized that the mathematical relations based on statistics are dependable and reliable. We know with a certain definiteness the range of scatter and deviation of the results. We know that very great deviations will occur but rarely. The claim that the forecaster can do as well without as with the aid of the formulæ is not sufficient. He must be able to surpass the formulæ, or his forecasting instinct is in the long run no better than the statistical equation. In other words, an examination of the current weather maps or the data bearing on a particular anticipated condition should enable the forecaster to conclude when the formula is going to fail, and shape his forecasts to accomplish a higher verification. If he is unable to do this his forecasting instinct is really of little avail, because the statistical methods will accomplish the same results without even considering the weather map or the current conditions. It would be interesting to conduct a comparative study to ascertain how much better a capable forecaster could do than the results arrived at by the statistical analysis.—*C. F. Marvin.*

INTRODUCTION.

As a result of the excellent pioneer work of J. Warren Smith, of the United States Weather Bureau, it is commonly believed that July rainfall is the all-important factor in determining the yield of corn in the central part of the corn belt. In the February, 1914, issue of the MONTHLY WEATHER REVIEW[1] J. Warren Smith examines in some detail by means of the correlation coefficient method the relationship between various weather factors and corn yield in the various corn-belt States and among other conclusions arrives at the following: "If the rainfall for calendar months be considered, that for July has a far greater effect upon the corn yield than rainfall for any other month."

Prof. Smith's conclusion as to the importance of rainfall in July in determining corn yields, while it is absolutely sound as far as Ohio and several other corn-belt States is concerned, does not apply to Iowa. The object of this paper is to examine, in somewhat greater detail than Prof. Smith has done in his published work, the relation between corn yield, rainfall, and temperature in the months of May, June, July, and August in each of the eight corn-belt States. For the most part the method of investigation will be by means of correlation coefficients, multiple coefficients of correlation, and lines of regression. The period studied in each State is a 29-year period from 1891 to 1919, inclusive.

Secular trend.—The secular or long-time trend of the corn yield for each State is determined after the customary manner such as is described on page 12 of the January, 1919, issue of the *Review of Economic Statistics*, published by Harvard University. The actual yields for each of the eight States for the 29-year period under consideration are taken from Department Bulletin 515 of United States Department of Agriculture and from the Yearbooks of the Department of Agriculture for 1916, 1917, 1918, and 1919. The method of secular trend when applied to the corn yields of Iowa for the 29-year period under consideration gives a value of 29.9 bushels for the year 1891, with an average yearly increase of 0.25 of a bushel, or 30.15 bushels for 1892, and so on by 0.25 bushel additions to 36.9 bushels for 1919. In like manner the normal corn yield in Ohio in 1919 based on the method of secular trend would be 40.5 bushels as compared with 30.7 bushels in 1891, the yearly addition since 1891 being 0.353 of a bushel. In Indiana the yearly addition is 0.233 bushel, the 1891 value is 31.1 bushels, and the 1919 value 37.6 bushels. In Illinois the average yearly increase is 0.12 bushel, the 1891 value is 32 bushels, and the 1919 value, 35.4 bushels. In Missouri* the average yearly increase is 0.044 bushels, the 1891 value is 26.9 bushels, and the 1919 value 28.1 bushels. In Nebraska* the secular trend is downward at the rate of 0.05 bushel annually, the value in 1891 being 26.2 and the value in 1919 being 24.8 bushels. In Kansas* the secular trend is also downward at the rate of 0.196 bushel annually from 22.7 bushels in 1891 to 17.2 bushels in 1919. In Minnesota the secular trend is upward at the rate of 0.342 bushel annually from 25.9 bushels in 1891 to 35.4 bushels in 1919.

Departures.—The next step is to determine the percentages which the actual yield is year by year above or below the normal yield as thus determined by the method of secular trend. For example, the normal yield in Iowa in 1919 was 36.9 bushels, according to the method of secular trend, whereas the actual yield was 41.6 bushels, or 13 per cent above. For each year of the 29-year period and for each of the eight States is determined in this way the percentage deviation of the actual yield from the normal yield as determined by the method of secular trend.

TEMPERATURES AND RAINFALL OF SUMMER MONTHS.

Averages.—Having determined the percentage deviations of the yields year by year above and below the normal as determined by the method of secular trend,

[1] 42: 78–93.

* In Kansas, Nebraska and Missouri the method of secular trend as applied to the 1891–1919 period may involve some error inasmuch as the weather seems to have been less favorable during the period 1911–1919 than during that of 1891–1899. In Kansas and Nebraska minor causes of the downward trend have been decrease in soil fertility and westward extension of the corn-growing area.

we next endeavor to determine to what extent these deviations are caused by deviations in the rainfall or temperature above or below the mean for the 29-year period. The average temperatures for the 29-year period for the eight corn-belt States for the months of May, June, July, and August are as follows:

TABLE 1.—*Average temperature (1891–1919).*

	May.	June.	July.	August.
	°F.	°F.	°F.	°F.
Iowa	59.8	69.2	74.0	72.0
Illinois	62.5	71.6	75.8	74.2
Indiana	62.4	71.3	75.3	73.6
Kansas	63.7	73.4	78.1	77.5
Minnesota	54.8	64.7	69.5	67.1
Missouri	64.9	73.4	77.3	76.3
Nebraska	58.9	68.9	74.3	72.8
Ohio	60.6	69.3	73.7	71.8

The average precipitation for the eight States for the months of May, June, July, and August is as follows:

TABLE 2.—*Average precipitation (1891–1919).*

	May.	June.	July.	August.
	Inches.	*Inches.*	*Inches.*	*Inches.*
Iowa	4.66	4.40	3.85	3.40
Illinois	4.22	3.84	3.49	3.32
Indiana	4.10	3.87	3.48	3.29
Kansas	4.67	4.63	3.73	3.32
Minnesota	3.51	4.17	3.63	3.40
Missouri	4.99	4.78	4.08	4.08
Nebraska	3.48	3.81	3.24	2.83
Ohio	3.73	3.79	3.94	3.27

Departures.—The next step is to determine the number of inches the precipitation is above or below the average year by year, as well as the number of the degrees the temperature is above or below the average year by year. For instance, in May, 1891, the Indiana actual rainfall was 1.6 inches, or 2.5 inches below the average of the 29-year period, which is 4.1 inches.

CORRELATION OF CORN YIELD WITH WEATHER.

After the deviations above or below the average in inches of precipitation or degrees of temperature have been secured for the months of May, June, July, and August for each of the eight States, the next thing to do is to find the correlation between the deviation of the yield from the normal as determined by secular trend and the deviation in the temperature or rainfall, as the case may be, for any given month.

May rainfall and corn yield in Kansas.—For example, determine the correlation between the yield of Kansas corn and the Kansas May rainfall. In 1891 the Kansas corn yield was 18 per cent above normal, and the Kansas May rainfall was 0.5 inch above the mean for the 29-year period. Likewise, in 1892 the Kansas corn yield was 9 per cent above normal, and the rainfall was 3 inches above the mean. The following table sets forth the values of the corn yield percentage deviations and the May rainfall deviation, the column of corn-yield deviations being called column A and the column of May rainfall deviations being called column B.

TABLE 3.—*Correlation of corn yield with May rainfall in Kansas.*

	A.	B.	AB.	
			Plus.	Minus.
1891	+18	+0.5	+ 9.0	
1892	+ 9	+3.0	+ 27.0	
1893	− 4	−0.8	+ 3.2	
1894	−49	−2.2	+ 107.8	
1895	+11	−2.3		−25.3
1896	+29	+1.2	+ 34.8	
1897	−16	−2.4	+ 38.4	
1898	−25	+1.9		−47.5
1899	+28	−0.4		−11.2
1900	− 9	−0.6	+ 5.4	
1901	−62	−2.9	+ 179.8	
1902	+46	+2.7	+ 124.2	
1903	+26	+5.3	+ 137.8	
1904	+ 4	+1.8	+ 7.2	
1905	+39	+0.2	+ 7.8	
1906	+47	−1.8		−84.6
1907	+13	−1.9		−24.7
1908	+13	+1.9	+ 24.7	
1909	+ 4	−0.3		− 1.2
1910	0	+1.4		
1911	−23	−1.9	+ 43.7	
1912	+24	−1.0		−24.0
1913	−83	−1.0	+ 83.0	
1914	+ 2	−1.5		−3.0
1915	+73	+3.0	+ 219.0	
1916	−60	−0.2	+ 12.0	
1917	−26	−0.5	+ 13.0	
1918	−42	0		
1919	−10	−1.1	+ 11.0	
Total			+1,088.8	−221.5

Summation AB=+867.3.

According to the method of correlation coefficients as used by Pearson and Yule the standard deviation of column A is 33.3, which, in effect, means that in Kansas the chances are about two out of three that the yield will not be more than 33.3 per cent above or below the normal. The standard deviation of column B is 1.94 inches, which means, in effect, that there are about two chances in three that the rainfall in May will not be more than 1.94 inches above or below the 4.7 mean. The summation of the product of column A by column B is 867.3. 867.3 divided by 29, which is the number of cases or years involved, is 29.9. 29.9 divided by the standard deviation of column A multiplied by the standard deviation of column B, or 64.6, gives +0.463. +0.463 is the correlation between Kansas corn yield and the Kansas May rainfall, perfect positive correlation being +1 and perfect negative correlation being −1.

Weather elements by months and corn yield in eight States.—By means of the method just illustrated correlation coefficients have been worked out in each of the eight States between yield, rainfall, and temperature in each of the four months, giving 64 correlation coefficients between yield and weather as in the following table:

TABLE 4.—*Correlation coefficients between corn, yield, and weather.*

	Yield and temperature.				Yield and rainfall.			
	May.	June.	July.	Aug.	May.	June.	July.	Aug.
Indiana	+0.200	−0.115	−0.474	+0.040	+0.072	+0.083	+0.591	+0.423
Illinois	+ .222	− .322	− .637	− .144	+ .096	+ .110	+ .651	+ .330
Iowa	+ .153	− .100	− .294	− .020	− .056	+ .117	+ .122	+ .273
Kansas	− .060	− .477	− .748	− .555	+ .463	+ .410	+ .776	+ .540
Minnesota	+ .224	+ .380	− .077	+ .400	+ .041	.000	+ .131	+ .422
Missouri	− .027	− .567	− .654	− .541	+ .203	+ .337	+ .534	+ .495
Nebraska	− .110	− .217	− .594	− .421	+ .432	+ .276	+ .587	+ .382
Ohio	+ .325	− .098	− .172	− .086	− .308	+ .132	+ .653	+ .350
Floyd County, Iowa	+ .320	+ .220	− .096	+ .170	+ .101	+ .083	− .085	+ .188
Polk County, Iowa	+ .085	− .382	− .510	− .240			+ .180	+ .492

Table 4 is worth very careful study. In the first place, I wish to call attention to the fact that so far as correlation between corn yield and rainfall in Ohio is concerned the results are practically identical with those of J. Warren Smith. His correlation between yield and June rainfall is +0.12 whereas mine is +0.132. For July rainfall he gets a correlation coefficient of +0.59 whereas mine is +0.653. For August he gets +0.37 whereas mine is +0.35.

So far as Ohio is concerned, July rainfall is unquestionably the dominating weather factor. The temperature in May, however, is also important, the correlation coefficient between May temperature and yield in Ohio being +0.325, which is almost as high as the correlation coefficient between August rainfall and yield.

In some States west of Ohio the temperature during July assumes an even more dominating part than the July rainfall. Note that in Illinois there is a correlation between July temperature and yield of −0.637, whereas between July rainfall and yield the correlation coefficient is +0.651. In Missouri there is a negative relation between July temperature and yield of −0.651, whereas between July rainfall and yield the correlation is only +0.534. July temperature seems to be even more important in Missouri than July rainfall. In Iowa and Minnesota it will be noted that July rainfall means practically nothing, the correlation coefficient being only +0.122 for Iowa and +0.131 for Minnesota. There is no very strong correlation coefficient for anything in Iowa, but the strongest is the negative relationship between July temperature and yield, of −0.294.

In each of the eight States I shall pick out factors which are more or less dominating so far as yield is concerned. For instance, in Indiana I shall take July temperature with a correlation coefficient of −0.474, July rainfall with a correlation coefficient of +0.591, and August rainfall with a correlation coefficient of +0.423. In the case of Illinois we shall take July temperature, July rainfall, and May temperature. It first glance it might be thought that August rainfall should be used instead of May temperature in view of the fact that the correlation coefficient between May temperature and rainfall is only +0.222. As a matter of fact, however, the correlation coefficient between August rainfall and corn yield in Illinois is more apparent than real, inasmuch as there is a tendency for dry Augusts to come in the same years as dry Julys, whereas there is only a very slight tendency for a hot May to be followed by heavy rainfall in July.

YIELD CORRELATED WITH COMBINATION OF THREE MOST IMPORTANT WEATHER FACTORS.

The next step is to find out the multiple coefficient of correlation between the yield on the one hand and the three selected factors on the other. This is done according to the following formula:

$$R^2=\frac{M}{1-r_{1,2}{}^2-r_{1,3}{}^2-r_{2,3}{}^2+2r_{1,2}r_{1,3}r_{2,3}}, \qquad \text{.....(1)}$$

where

$$M=\left\{\begin{matrix}(r_{0,1}{}^2+r_{0,2}{}^2+r_{0,3}{}^2-r_{0,1}{}^2r_{2,3}{}^2-r_{0,2}{}^2r_{1,3}{}^2-r_{0,3}{}^2r_{1,2}{}^2)\\ -2(r_{0,1}r_{0,2}r_{1,2}+r_{0,1}r_{0,3}r_{1,3}+r_{0,2}r_{0,3}r_{2,3})\\ +2(r_{0,1}r_{0,2}r_{1,3}r_{2,3}+r_{0,1}r_{0,3}r_{1,2}r_{2,3}+r_{0,2}r_{0,3}r_{1,2}r_{1,3})\end{matrix}\right\}$$

To apply this formula, suppose we take Missouri, for example, allowing 0 to represent the percentage deviation of the yield; 1 to represent deviation of June temperature in degrees above and below the mean; 2 to represent the deviation of July temperature; and 3 to represent deviation of August temperatures. $r_{0,1}$ represents the correlation coefficient between yield and June temperature; $r_{0,2}$ the correlation coefficient between yield and July temperature; $r_{0,3}$ between yield and August temperature; $r_{1,2}$ between June temperature and July temperature; $r_{1,3}$ between June temperature and August temperature; $r_{2,3}$ between July temperature and August temperature. Solving the equation and securing the multiple coefficient of correlation between yield in Missouri and the deviations of the June, July, and August temperature we secure as the multiple coefficient of correlation, 0.79.

TABLE 5.—*Multiple correlation coefficients between deviations of weather factors and corn yield.*

State.	Weather combination.	Correlation coefficient.
Missouri	June temperature, July temperature, August temperature.	0.79
Iowa	May temperature, July temperature, August rain.	.464
Iowa, Polk County	June temperature, July temperature, August rain.	.62
Iowa, Floyd County	May temperature, June temperature, August rain.	.405
Nebraska	May rain, July temperature, July rain	.67
Indiana	July temperature, July rain, August rain	.66
Minnesota	June temperature, August temperature, August rain.	.56
Ohio	May temperature, July rain, August rain	.746
Illinois	May temperature, July temperature, July rain	.81
Kansas	June rain, July rain, August rain	.862

LINES OF REGRESSION.

In the case of every State, with the possible exception of Iowa and Minnesota, these multiple coefficients of correlation are high enough to indicate that it is worth while going ahead and working out lines of regression, which we shall therefore undertake to do as the next step. The formula for working out the line of regression in a case of this sort where there are three factors determining a fourth factor is as follows:

$$x_0=a_1x_1+a_2x_2+a_3r_3 \qquad \text{.....(2)}$$

where

$$a_1=\frac{r_{0,1}(1-r_{2,3}{}^2)+r_{0,2}(r_{1,3}r_{2,3}-r_{1,2})+r_{0,3}(r_{1,2}r_{2,3}-r_{1,3})\sigma_0}{(1-r_{2,3}{}^2)+r_{1,2}(r_{1,3}r_{2,3}-r_{1,2})+r_{1,3}(r_{1,2}r_{2,3}-r_{1,3})\sigma_1}$$

$$a_2=\frac{r_{0,2}(1-r_{1,3}{}^2)+r_{0,3}(r_{1,2}r_{1,3}-r_{2,3})+r_{0,1}(r_{1,3}r_{2,3}-r_{1,2})\sigma_0}{(1-r_{1,3}{}^2)+r_{2,3}(r_{1,2}r_{1,3}-r_{2,3})+r_{1,2}(r_{1,3}r_{2,3}-r_{1,2})\sigma_2}$$

$$a_3=\frac{r_{0,3}(1-r_{1,2}{}^2)+r_{0,2}(r_{1,2}r_{1,3}-r_{2,3})+r_{0,1}(r_{1,2}r_{2,3}-r_{1,3})\sigma_0}{(1-r_{1,2}{}^2)+r_{2,3}(r_{1,2}r_{1,3}-r_{2,3})+r_{1,3}(r_{1,2}r_{2,3}-r_{1,3})\sigma_3}$$

Missouri corn yield.—Solving this formula, we find as an answer in the case of Missouri:

The percentage deviation in the yield of corn equals −2.8 of the departure of the June temperature from the average, in degrees, −4 of the departure of the July temperature from the average, in degrees, −1.5 of the departure of the August temperature from the average, in degrees.

The average June temperature for Missouri is 73.4° F., the average July temperature, 77.3° F., and the averaeg August temperature, 76.3° F. At the present time the normal corn yield in Missouri according to the method of secular trend is 28.1 bushels. Translating our last equation, we find that it means that at the present time for each degree June temperature is above 73.4° F. in Missouri the chances are that the Missouri corn yield will be cut by 0.8 bushels, whereas, for each degree that the June temperature in Missouri is below 73.4° F. the corn yield will be increased by 0.8 bushels. In the case of

July, for each degree that the Missouri temperature is above 77.3° F. the corn yield will be cut by 1.1 bushels, whereas for each degree that it is below 77.3° F. it will be increased by 1.1 bushels. In like manner, for each degree that the August temperature is above 76.3° F. the Missouri corn yield will be cut by 0.4 bushels, whereas for each degree that the Missouri August temperature is below 76.3° F. the yield will be increased by 0.4 bushels. Taking a specific case, when in Missouri the June temperature is 72.4° F., the July temperature, 75.3° F., and the August temperature, 75.3° F., we should expect a yield 0.8 bushels above normal because of the low June temperature, 2.2 bushels above normal because of the low July temperature, and 0.4 bushel above normal because of the August temperature, or a total of 3.4 bushels above normal, or a yield of 31.5 bushels per acre.

Predicted from formula, the yield of Missouri corn in 1891 should have been 23 per cent above the normal, whereas actually it was only 11 per cent; in 1892 it should have been 6 per cent above normal, whereas actually it was 2 per cent; in 1895 predicted from formula it should have been 14 per cent above normal, whereas actually it was 33 per cent; in 1901 it should have been 48 per cent below normal, whereas actually it was 63 per cent below normal. In spite of the rather high multiple coefficient of correlation of 0.79, our prediction formula is still somewhat inaccurate. Perhaps other weather factors than June, July, and August temperature should be taken into consideration. One of these is May temperature; and it is found that there is a correlation coefficient between May temperature and the discrepancies between the predicted yield and the actual yield of 0.22. Again making a new predicted yield on the basis of May temperatures being accounted for, we still find considerable discrepancy, and on examining the matter further we find that July and August rainfall combined correlates with these discrepancies to the extent of 0.41 (provided that the year 1915 is left out).

While as a general rule the corn yield in Missouri increases with low temperatures in June, July, and August, yet there is a possibility of too low temperatures even in Missouri. Also, there is a possibility of danger by too heavy sudden rains even in Missouri, although, as a general rule, the heavier the rain during the summer, the larger the corn yield. In 1915 the temperature and rainfall was such that according to the strict mathematical formula we should have expected a yield fully 27 per cent above normal. As a matter of fact, however, the weather in 1915 went to the extreme of being too cold and too wet even for Missouri conditions, and the yield was only 6 per cent above normal.[2] 1904 is an example of somewhat similar conditions, the season being too cold and wet for Missouri. In extremely cold, wet seasons in Missouri the result normally is a crop which is about average, instead of a crop 25 per cent to 30 per cent above normal, as would be expected from a strict interpretation of the mathematical formula. It is necessary that there should be an average temperature deficiency below the average of at least 2½° for each of the months of June, July, and August in order to prevent Missouri corn from being benefited by coolness and wetness.

[2] Flooded bottoms cut the yield.—C. F. B.

PREDICTING FORMULÆ FOR CORN YIELDS.

The following predicting formulæ have been worked out for each of the States by means of formula (2).

Iowa:

$$x_0=0.77x_1-1.4x_2+1.26x_3$$

where x_0=per cent deviation of yield.
x_1=deviation of May temperature from average in degrees.
x_2=deviation of July temperature from average in degrees.
x_3=deviation of August rain from average in inches.

Illinois:

$$x_0=0.98x_1-4.33x_2+4.38x_3$$

where x_0=per cent deviation in yield.
x_1=deviation of May temperature from average in degrees.
x_2=deviation of July temperature from average in degrees.
x_3=deviation of July rain from average in inches.

Ohio:

$$x_0=0.8x_1+1.9x_2+0.9x_3$$

where x_0=per cent deviation of yield.
x_1=deviation of May temperature from average in degrees.
x_2=deviation of July rain from average in inches.
x_3=deviation of August rain from average in inches.

Kansas:

$$x_0=3.7x_1+10.7x_2+7.5x_3$$

where x_0=per cent deviation of yield.
x_1=deviation of June rain from average in inches.
x_2=deviation of July rain from average in inches.
x_3=deviation of August rain from average in inches.

Minnesota:

$$x_0=1.6x_1+0.8x_2+4.2x_3$$

where x_0=per cent deviation of yield.
x_1=deviation of June temperature from average in degrees.
x_2=deviation of August temperature from average in degrees.
x_3=deviation of August rain from average in inches.

In applying the Minnesota formula to the Minnesota averages it is well to remember that the average temperature for Minnesota as a whole is about 2° below the average of the corn-growing part of Minnesota. For corn-growing Minnesota the St. Paul temperature figures are probably better than those for the State as a whole. The St. Paul averages are 58° for May, 67° for June, 72° for July, and 69° for August.

Floyd County, Iowa:

$$x_0=1.65x_1+1.14x_2+1.83x_3$$

where x_0=deviation in per cent of yield.
x_1=deviation of May temperature from average in degrees.
x_2=deviation of June temperature from average in degrees.
x_3=deviation of August rain from average in inches.

Polk County, Iowa:

$$x_0=-0.8x_1-2.4x_2+3.4x_3$$

where x_0=per cent deviation of yield.
x_1=deviation of June temperature from average in degrees.
x_2=deviation of July temperature from average in degrees.
x_3=deviation of August rain from average in inches.

Indiana:

$$x_0=-1.6x_1+3.6x_2+1.5x_3$$

where x_0=per cent deviation of yield.
x_1=deviation of July temperature from average in degrees.
x_2=deviation of July rain from average in inches.
x_3=deviation of August rain from average in inches.

Nebraska:

$$x_0=3.48x_1-2.96x_2+3.08x_3$$

where x_0=per cent deviation of yield.
x_1=deviation of May rain from average in inches.
x_2=deviation of July temperature from average in degrees.
x_3=deviation of July rain from average in inches.

IOWA WEATHER AND YIELD OF CORN.

In Iowa the multiple coefficient of correlation between yield and May temperature, July temperature, and August rain is disappointingly low, being only 0.464.

Since Iowa is probably the most important of all the corn States, it is felt to be decidedly worth while to work out the Iowa weather-corn yield problem in considerable detail. Superficial examination of the evidence leads to the conclusion that the low correlation coefficient in Iowa is due to the fact that in Iowa there are some seasons and some sections when the yield is short because of the too cool weather during the greater part of the summer, whereas in other years the yield is too short because of too hot weather. Also it is a matter of observation that in exceedingly hot seasons the yield is oftentimes excellent in northern Iowa, whereas in southern Iowa the yield will be very seriously damaged, and vice versa in cool seasons. Obviously, therefore, the method of correlation coefficients is not very well adapted to examining the effect of weather on corn yield in Iowa.

TEMPERATURE AND RAINFALL AS AFFECTING THE YIELD OF CORN IN POLK COUNTY, IOWA.

In order to get a little closer to the problem let us work with Polk County, Iowa, for the 29-year period, 1891 to 1919, inclusive. The yields in this case are taken from the Iowa State Crop Reporting Service and the secular trend is secured for these yields and the percentage deviations above and below the normal is secured in just the same way as for the eight corn-belt States. Temperatures and rainfall are taken from the reports of the Des Moines weather bureau as compiled and published by Chas. D. Reed, of the Des Moines weather bureau, in a little pamphlet early in 1920. Using the method of correlation coefficients we find that the relationship between May temperature and corn yield in Polk County, Iowa, is +0.085, between June temperature and corn yield −0.382, between July temperature and corn yield −0.510, between August temperature and corn yield −0.240, between July rainfall and corn yield 0.180, and between August rainfall and corn yield 0.492. The three most important factors apparently are June temperature, July temperature, and August rainfall. The multiple coefficient of correlation between these three factors and the yield is 0.62, which is somewhat higher than the multiple coefficient of correlation secured for the entire State between the three leading factors and the yield. Applying now common sense to the data and realizing that certain years can be too cold for corn in Polk County and others too hot, and that especially May, June, and August can be too cold, we arrive roughly by the cut-and-try method, backed up, also, by our preliminary examination by means of correlation coefficients, at the following tables:

TABLE 6a.—*Corn yield in Polk County, Iowa, as affected by May temperature.*

Temperature.	Corn yield.	Temperature.	Corn yield.
55° F.	15 per cent cut from the normal as secured by method of secular trend.	61° F.	1 per cent above normal.
		62°	2 per cent increase above normal.
56°	5 per cent cut from normal.	63°	3 per cent increase above normal.
57°	3 per cent cut from normal.	64° or higher.	4 per cent increase above normal.
58°	2 per cent cut from normal.		
59°	1 per cent cut from normal.		
60°	No cut from normal.		

TABLE 6b.—*Corn yield in Polk County, Iowa, as affected by June temperature.*

Temperature.	Corn yield.	Temperature.	Corn yield.
65° F.	5 per cent cut from normal as secured by method of secular trend.	71° F.	1 per cent above normal.
		72°	No increase above normal.
66°	2 per cent cut from normal.	73°	1 per cent cut from normal.
67°	1 per cent cut from normal.	74°	2 per cent cut from normal.
68°	No cut from normal.	75°	3 per cent cut from normal.
69°	1 per cent increase above normal.	76°	4 per cent cut from normal.
		77°	5 per cent cut from normal.
70°	2 per cent increase above normal.		

It will be noted that in the case of June temperature it is assumed that both exceedingly low and exceedingly high temperatures are harmful to corn, and that there is a range of from about 68° to 72° that is neutral or slightly beneficial. It might very possibly be true that a temperature of 77° in June would not cut the yield by as much as 5 per cent provided there was plenty of rain. However, so far as Polk County is concerned we have no means of knowing whether or not this would be the case, inasmuch as the only year when the temperature was anywhere near this high was in 1911, when the temperature was 77.5° and when the rainfall was 0.75 inch. It might very well be, therefore, that the higher temperatures in June would not prove harmful provided there were more than 3 inches of rainfall. In fact, it is believed that with 3 inches or more of rainfall temperatures up to 75°, at least, might prove to be distinctly beneficial. So far as Polk County is concerned, however, it seems scarcely worth while to construct a chart taking into consideration both rainfall and temperature in June, inasmuch as only once during the past 29 years has the temperature been so very high and the rainfall moderately heavy. In June, 1914, the temperature was 74.4° and the rainfall was 3.9 inches. This combination of moderately high June temperature with good rain proved to be decidedly favorable, but it is the only year of its kind on which to base a judgment

TABLE 6c.—*Corn yield in Polk County, Iowa, affected by August temperature.*

Temperature.	Corn yield.	Temperature.	Corn yield.
67° F.	10 per cent cut below normal corn yield as secured by method of secular trend.	73° F.	3 per cent increase above normal.
		74°	2 per cent increase above normal.
68°	6 per cent cut below normal.	75°	1 per cent increase above normal.
69°	3 per cent cut below normal.	76°	3 per cent cut below normal.
70°	1 per cent cut below normal.	77°	6 per cent cut below normal.
71°	1 per cent increase above normal.	78°	12 per cent cut below normal.
72°	3 per cent increase above normal.	79°	20 per cent cut below normal.

Moderately warm weather during August is essential to ripen up the corn in Polk County, especially if the season earlier has been at all backward. However, if the temperature during August averages 76° the chances are that there has been some exceedingly hot weather during the first 10 or 12 days of August, and that this hot weather has come just at the time when hot weather and drought are likely to do the corn the most damage, just when the kernels are first being formed. It is

believed, therefore, that the very sudden increase in the size of the cuts in the lower part of the August temperature table is well founded.

So far as the month of July is concerned, it will be remembered that there is a (negative) correlation of −0.51 between July temperature and the corn yield in Polk County, indicating that ordinarily the cooler the July the greater the corn yield. When the temperature averages below 71° in July, however, it is very doubtful if the corn plant is benefited by any further decrease in temperature, especially if the rainfall is heavy and there is rather less than the normal amount of sunshine. Reasoning from the data presented by Prof. T. A. Kiesselbach in Research Bulletin No. 6 of the University of Nebraska, we know that corn plants transpire moisture much less rapidly when the temperature is 70° than when the temperature is 80°. Prof. Kiesselbach's data would indicate, in fact, that a normal acre of corn plants during 30 days of the middle of the summer will transpire at the rate of about 3½ inches of rainfall when the mean temperature is around 70°, as compared with over 6 inches of rainfall when the temperature is over 80°. Not only will the corn plants themselves transpire far more moisture through their leaves when the temperature is 80° than when the temperature is 70°, but there will also be a tendency for a greater evaporation of moisture from the soil itself. It is believed that the chief effect of high temperatures in July on the corn plant in Polk County is rather indirect, through causing increased transpiration of water through the leaves of the corn plant. On this assumption, therefore, the following table has been prepared which indicates the theoretical increases or cuts to be made in the corn yield from the normal base as secured by the method of secular trend.

TABLE 7.—*Relation between Polk County, Iowa, corn yield and different amounts of July rainfall and different degrees of July temperature.*

Inches rain.	0.25	0.50	0.75	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0 or more.
°F.														
68	.....	.....	.....	.....	.....	.....	+ 6	+ 5	+ 3	+ 2	+ 1	0	0	− 3
69	.....	.....	.....	.....	.....	.....	+13	+12	+10	+ 8	+ 6	+ 4	+ 2	0
70	.....	.....	.....	.....	.....	.....	+14	+14	+14	+14	+13	+ 9	+ 5	+ 3
71	.....	.....	.....	.....	.....	+12	+15	+18	+20	+18	+14	+12	+ 9	+ 5
72	.....	.....	.....	.....	.....	+10	+13	+16	+18	+20	+16	+13	+10	+ 6
73	.....	.....	.....	.....	.....	+ 9	+12	+15	+17	+20	+18	+14	+12	+ 7
74	.....	.....	.....	.....	+ 5	+ 8	+11	+14	+17	+20	+18	+15	+12	+ 8
75	.....	.....	.....	.....	+ 4	+ 7	+10	+13	+17	+20	+18	+16	+13	+ 9
76	−25	−15	− 3	0	+ 3	+ 6	+ 9	+12	+16	+19	+18	+17	+13	+10
77	−35	−22	−10	− 6	+ 1	+ 4	+ 7	.....	.....	.....	.....	.....	.....	.....
78	−45	−30	−15	− 9	− 2	+ 1	+ 4	.....	.....	.....	.....	.....	.....	.....
79	−55	−35	−20	−14	− 5	− 2	+ 1	.....	.....	.....	.....	.....	.....	.....
80	−65	−40	−25	−18	− 9	− 5	− 2	.....	.....	.....	.....	.....	.....	.....
81	−75	−45	−35	−24	−13	− 8	.....	.....	.....	.....	.....	.....	.....	.....
82	−85	−50	−45	−31	−18	−11	.....	.....	.....	.....	.....	.....	.....	.....
83	.....	−60	−50	−38	−24	−15	.....	.....	.....	.....	.....	.....	.....	.....
84	.....	−65	−55	−45	−30	−20	.....	.....	.....	.....	.....	.....	.....	.....

All practical farmers know that heavy May rainfall harms the corn crop in Polk County by delaying the preparation of the seed-bed and by delaying the date of planting. I therefore give the following table:

TABLE 8.—*Relation between corn yield and May rainfall in Polk County, Iowa.*

Rainfall.	Corn yield.	Rainfall.	Corn yield.
Inches.		*Inches.*	
11	10 per cent cut below normal as secured by method of secular trend.	9	6 per cent cut below normal.
		8	4 per cent cut below normal.
		7	3 per cent cut below normal.
10	8 per cent cut below normal.	6	1 per cent cut below normal.

With soil of the type prevailing over the greater part of Polk County there is a considerable reserve supply of moisture carried into the months of July and August from earlier in the season. Prof. Kiesselbach's experiments with measuring the transpiration from corn plants (op. cit.) indicate that there is a period of 20 or 30 days in late July and early August when corn is drawing on the soil for nearly twice as much water as normally falls at that time. The reserve supply of moisture carried over, therefore, from early in the season may occasionally become a determining factor. The following table is devised for the purpose of taking into account this proposition of a reserve supply of moisture, a proposition which becomes especially important in seasons when the months of May, June, and July are hot as well as dry.

If the 92-day period from May 1 to July 1 has averaged over 70° daily, and the July rainfall is less than 3 inches, the yield will vary from the normal according to the total rainfall in April, May, June, and July, in inches, as follows:

TABLE 9.—*Relation between corn yield and total rainfall in April, May, June, and July in Polk County, Iowa.*

Total rainfall.	Corn yield.	Total rainfall.	Corn yield.
Inches.		*Inches.*	
5	25 per cent cut from the normal as secured by the method of secular trend.	9	4 per cent cut.
		10	No cut.
		11	4 per cent increase.
6	20 per cent cut.	12	8 per cent increase.
7	14 per cent cut.	13	12 per cent increase.
8	8 per cent cut.	18	14 per cent increase.

It is believed that this matter of reserve rainfall is chiefly important only in years when the three months of May, June, and July have been unusually warm. The only years of this character in the past 29 years in Polk County have been 1894, 1901, 1911, 1913, 1914, 1918, and 1919. In 1894 the total rainfall during the months of April, May, June, and July was only 5 inches, and it is obvious that this very small amount of early-summer rainfall must have very much intensified the serious effects of the drought and heat in July and August. Again, in 1901 there was a total of only 8 inches of rainfall in the months of April, May, June, and July, and again the effects of late summer heat and drought were intensified. In 1918 and 1919, however, there were 14 and 18 inches of rainfall, respectively, in the four-months period from April to July, inclusive. This rainfall was enough to create somewhat of a reserve to withstand a very considerable degree of heat and drought during July and August of 1918 and 1919.

Still one more table is necessary, that dealing with the effect of August rainfall on Polk County corn yield:

TABLE 10.—*Effect of August rainfall on Polk County corn yield.*

Rainfall.	Corn yield.	Rainfall.	Corn yield.
Inches.		*Inches.*	
0.5	20 per cent cut below normal as secured by method of secular trend.	3	1 per cent increase above normal.
		3.5	2 per cent increase above normal.
1.5	15 per cent cut below normal.	4	3 per cent increase above normal.
2	7 per cent cut below normal.		
2.5	3 per cent cut below normal.	4.5	4 per cent increase above normal.
	No cut below normal.		

By using the foregoing tables (6–10) it is possible to predict the yield of corn in Polk County, Iowa, with considerable accuracy, the correlation between the predicted yield and the actual yield being 0.92.

The most marked discrepancy between the predicted yield as secured by the tables and the actual yield was in the year 1897, when the actual yield was 17 per cent below normal, and the predicted was 6 per cent above. In 1897 the damage, without much question, was caused by a cumulative drought. After a rainfall of 7 inches in April, the drought began, and there were only 2.3 inches of rain in May, 3.1 inches in June, 2.9 inches in July, 1.8 inches in August, and 1.6 inches in September. Ordinarily Polk County corn does very nicely with a rainfall of 2.9 inches in July and 1.8 inches in August, provided the temperatures are not too high. In this particular year (1897), however, it would seem that the very heavy rainfall in April must have delayed plowing or put the soil out of condition, or, possibly, that the rather short May and June rainfall allowed the slightly deficient July and August rainfall to have a greater effect than would otherwise have been the case.

Beginning north of Des Moines about 50 miles and extending to the Minnesota border is a wonderful corn-growing section, which, so far as the relation of climate to corn yield is concerned, is of an altogether different type from that section from Des Moines south. For instance, in Floyd County there are the following correlation coefficients between various weather factors and the corn yield, for the 1891–1919 period: May temperature +0.32, June temperature +0.22, July temperature −0.10, August temperature +0.17, July rainfall −0.09, August rainfall +0.19, May rainfall +0.101, and June rainfall +0.083. Warm Mays are apparently much more important in Floyd County than in Polk County. Junes and Augusts which are warmer than the average tend to help the corn yield in Floyd County whereas in Polk County those Junes and Augusts which are warmer than the average ordinarily harm the corn yield. When an attempt is made to draw up a schedule of tables for Floyd County as for Polk County, it is found that there are a number of difficulties in the way. There are too many years when the season apparently contradicts itself.

In a season which is of a distinct type throughout, such as 1915, which was cool and wet, it may work all right to say that the 1915 May temperature of 53° cut the yield by 10 per cent, that the 62° June temperature cut the yield 20 per cent, and the 64° August temperature cut the yield another 20 per cent, making a total cut of 50 per cent. When a given season is mixed in its tendencies, however, it is difficult to predict just what will happen in northern Iowa. For instance, in 1912 May and July were warm, whereas June and August were cool. The rainfall was practically normal throughout. Any system of tables which would apply to the bulk of the past 29 years in Floyd County would credit the year 1912 with a crop only slightly above normal, whereas it actually was estimated at 42 per cent above normal.

While the correlation coefficients for Floyd county do not reveal any tendencies for the corn yield to be seriously affected by heat and drought in July and August, there nevertheless were certain years when the yield was unquestionably very seriously cut by heat and drought during the latter part of the summer, notably in 1894 and 1901—an accumulative drought existing since spring causing the trouble in 1894 and high July heat causing the trouble in 1901.

Even in northern Iowa it should be possible after very careful study to devise some kind of system of estimating the corn yield from the weather with a fair degree of accuracy. However, it will never be possible to estimate the corn yield in northern Iowa by knowing the weather with as great a degree of accuracy as is possible in the rest of the corn belt. Too much rainfall very often causes damage in the northern part of Iowa, but it is impossible to tell merely by examining monthly rainfall records just when the rainfall was too heavy. The worst corn crop failure of the past 29 years in Floyd County was in 1915, a year when the four months of May, June, July, and August averaged 5° below normal and when the May rainfall was 3 inches above normal. In 1891, when the temperature for the four summer months was almost as low as in 1915, with an average of 4.5° below normal for the four summer months, the yield was 12 per cent above normal; but in 1892 the rainfall in May was only 1.9 inches, or nearly 2 inches below normal. It seems to be a double combination of cold and wet which does the most damage in Floyd County, and probably in northern Iowa generally. The year of heaviest May rainfall in Floyd County was in 1902, with 9.2 inches, but that year the May temperature was 5° above normal and the yield of corn was 12 per cent above normal. More or less superficial examination of the data, backed up by a study of correlation coefficients, would lead to the conclusion that cold during May, June, and August does considerably more damage than an excess of rain, but that cold will not do its maximum damage unless accompanied by heavy rain, especially in May. It is suggested that unduly heavy rains during July and early August may possibly damage the corn yield in northern Iowa in rather backward seasons by decreasing the amount of sunshine, the effect of the decreased amount of sunshine being felt only in years when the temperature throughout the summer is rather below normal.

CONCLUSIONS.

July rainfall, while a dominating factor in determining corn yield in Ohio, is not such a dominating factor in many of the other corn-belt States, and in northern Iowa especially July rainfall ordinarily has very little influence on corn yield. Each State is a specific problem in itself, and the probabilities are that each county in a State is a specific problem. In Polk County, Iowa, for instance, it was found that there is a tendency for warm Junes to harm the corn yield, each degree of increase in temperature cutting the corn yield by 0.8 of 1 per cent, whereas in Floyd County, Iowa, only 150 miles farther north, warm Junes benefit the corn yield, each degree increase in June temperature adding 1 per cent to the corn yield.

The problem of predicting corn yield from the weather is relatively simple in the southern half of the corn belt, notably in Kansas, Missouri, and southern Illinois where drought and heat in June, July, and August are the chief influences. The problem is to measure the degree of the drought and heat with accuracy.

Careful examination of the rainfall, temperature, and corn yield data in the various corn-belt States leads to the belief that while the method of correlation coefficients is very useful for preliminary examination of the data, and while this method gives fairly good predicting formulæ in the southern part of the corn belt, yet it is not at all well adapted to the northern part of the corn belt, and especially to notthern Iowa. The relationship between corn yield and July temperature, for instance, is not strictly linear, but more in the nature of a horse-shoe curve. For instance, when the July temperature is 68° the yield may possibly tend to be 6 per cent above

normal; when it is 69° the yield may tend to be 13 per cent above normal; when it is 70° the yield may tend to be 14 per cent above normal; when it is 71° the yield may tend to be 15 per cent above normal; when it is 72° the yield may tend to be 13 per cent above normal; when it is 73° the yield may tend to be 12 per cent above normal; when it is 74° the yield may tend to be 10 per cent above normal; when it is 75° the yield may tend to be 8 per cent above normal; when it is 76° the yield may tend to be 6 per cent above normal; when it is 77° the yield may tend to be 4 per cent above normal; when it is 78° the yield may tend to be 2 per cent above normal; when it is 79° the yield may tend to be 2 per cent below normal. (This is when the rainfall is constant.) July rainfall and corn yield also apparently tend to have a relationship of somewhat this type, a rain of more than 4½ inches in July ordinarily doing little if any more good than a rainfall of 4 inches. In fact, in some years exceedingly heavy July rains seem to have done harm in northern Iowa. Practically none of the weather factors has a strictly linear relationship to corn yield. In the case of May temperature, for instance, a temperature of less than 54° is apparently very severely damaging in the north central part of the corn belt, much more damaging than a straight line of regression would indicate. In years when the May temperature is 6° or 7° below normal it is probable that the yield is cut 20 per cent or 25 per cent below normal, whereas the method of a straight line of regression would indicate a cut of only about 7 per cent below normal. When the temperature is only 2° below normal, however, it is doubtful if the corn yield is really affected by as much as the 2 per cent which the line of regression would indicate. There is a need of developing special types of curves for expressing the different relationships more accurately than straight lines of regression express it. For practical purposes it is probably just as well first to get a general idea of the importance of the various factors at work by using the theory of multiple correlation, and then by applying common sense derived from observation of the methods of corn culture in various sections work out tables somewhat after the fashion of the tables worked out in predicting the yield of corn in Polk County, Iowa. These tables are rather roughly worked out and are certainly open to objection from the standpoint of refined mathematics, but they illustrate the principles involved.

DISCUSSION.

(1) In the central portions of the corn belt much of the corn is grown on bottom lands, subject to overflow. In years of late spring or early summer floods, this corn has to be replanted, and this delays it so much that it is likely to be frosted before reaching maturity. In consequence, the yield for the State is reduced. This disturbing factor, only indirectly connected with the weather of the particular State, could be eliminated by using figures of the yield per acre of corn harvested for grain.

(2) Owing to the differences in the dates of planting corn one year and another, the weather of a particular month does not affect corn in the same way year after year, even if the weather of that month should be identical in, say, two years under consideration. This difficulty could be eliminated by taking the weather not by calendar months but by periods following the mean date when corn was planted in the region each year.

(3) The use of periods as long as a month is unsatisfactory in that a certain month with a mean temperature about normal may appear to have had usual temperatures when in reality it was one with a very hot period and a very cool period, a combination not at all unlikely to occur. The week would seem to be the better unit to use.

(4) Considering (2) and (3) above in conjunction, Prof. Smith's studies of the effect of weather for the 10 days following the average date of tasseling, for example, if applied individually to each year instead of by use of averages, would probably give consistent results.

(5) In the northern part of the corn belt much of the corn is planted without any real hope of harvesting it for grain. In a good year, that is, in a year with weather that would be normal 100 or 200 miles farther south, the corn is harvested with as good a yield as is usually obtained a little farther south. In a poor year, when the weather delays the crop, or when a frost comes unusually early, the corn is harvested for silage. It is evident that the weather of May, June, July, and August may actually be ideal for corn, but yet an early frost may reduce the yield 20 per cent or lower over a large portion of the northern part of the corn belt. This would be like throwing a monkey-wrench into the wheels of the formula.

Thus, the length of the growing season each year and the speed of the development of the crop are important factors to be considered in computing the yield for the northern part of the corn belt.

To make a study in accordance with these suggestions would probably require an impossible amount of labor for one person. But if one investigator takes one aspect or one locality and others do likewise, there may be some hope of a mathematical solution of the effect of weather on crop yields along much more detailed lines than hitherto.—*Charles F. Brooks.*

DAMAGE TO CROPS BY WEATHER.

The Bureau of Crop Estimates publishes a table in the *Monthly Crop Reporter* each year showing the per cent of damage to crops in the United States due to different causes. The figures are from estimates by their large corps of crop correspondents, and "may be regarded as index numbers reflecting the relative influence yearly of different factors affecting yields."

The table below gives the average damage, by the different factors, for the period from 1909 to 1919, inclusive, except for apples and berries, which is from 1912 to 1919:

	Deficient moisture.	Excessive moisture.	Floods.	Frost or freeze.	Hail.	Hot winds.	Storms.	Total weather.	Plant disease.	Insect pests.	Animal pests.	Defective seed.	Total.
Wheat	12.4	2.0	0.3	4.5	1.1	2.0	0.3	22.9	2.7	2.1	0.2	0.2	28.8
Corn	16.3	4.0	.9	2.9	.4	2.2	.5	27.7	.2	2.7	.2	.7	32.1
Oats	13.4	2.7	.3	.8	.8	1.9	.4	20.8	1.7	.9	.1	.2	24.5
Barley	17.1	1.8	.1	.8	1.3	3.2	.4	24.9	1.7	.7	.3	.1	28.7
Flax	21.1	1.3	.1	4.0	1.7	3.0	.2	31.8	2.2	.9	.1	.3	36.4
Rice	6.7	3.1	1.5	.3	(1)	.4	1.8	14.1	1.2	.8	.3	.1	19.0
Potatoes	14.4	3.1	.2	1.6	.1	.7	.1	20.7	4.4	3.2	.1	.3	30.0
Tobacco	8.7	3.7	.6	1.1	.8	.2	.3	15.8	.4	2.6	.....	.1	20.5
Hay	13.4	1.7	.3	1.7	.1	.6	.2	18.4	.1	.5	.1	.1	20.4
Apples	5.4	1.6	.2	14.6	.8	.5	.9	24.9	3.7	3.6	.1	.....	39.6
Berries	9.3	1.7	.2	7.3	.5	.6	.2	20.3	1.1	.6	.1	.....	24.9
Cotton	12.3	4.3	1.0	1.4	.5	1.6	.7	22.3	2.0	9.7	(1)	.2	35.5

[1] Less than 0.05 per cent.

It will be noted that a very large part of the total damage or loss is due to unfavorable weather; also that deficient moisture is the greatest single damaging factor in connection with every crop, except apples. Low temperature causes nearly three times as much damage to apples as dry weather.—*J. Warren Smith.*

WEATHER AND CROPS IN ARKANSAS, 1819 TO 1879.

By W. C. HICKMON, Observer.

[Weather Bureau Office, Little Rock, Ark., June 17, 1920.]

SYNOPSIS.

Arkansas Territory was formed July 4, 1819, the State admitted June 15, 1836. Since that time much has been said of Arkansas's "slow train," her swamp land, and mosquitoes; very little of her delightful climate or her abundant crops.

During the 60 years from 1819 to 1879 a fairly complete weather record was kept by Mr. William E. Woodruff and other early pioneers and published in the Territorial and early State newspapers.

From this record we find that extreme temperatures have been rare, the coldest winter probably being 1820–21, though a lower temperature (−11°) was recorded in February, 1823. Dry spells have frequently damaged crops during the summer months, the year 1838 being long remembered because of its continued drought, but good years far outnumber bad ones. Few things of importance escaped the notice of Mr. Woodruff. We find a description of the first Territorial Christmas; the meteor shower in November, 1833; the low water of 1838; and even a flood on the Town Branch received mention.

Considerable additional information was obtained regarding early high-river stages, especially on the Arkansas. That this information is reliable is quite evident from the minute description and painstaking care with which Mr. Woodruff goes into the details of several floods, notably the one in June, 1833.

As Arkansas began her career as a Territory and a State long before the Weather Bureau or the Smithsonian Institution began keeping a weather record in this section, an effort has been made to collect all available reliable information regarding early weather and crop conditions of the State and to connect our present record, which begins in 1879, with 1819, the year Arkansas Territory was created.

The data from which this paper is prepared were obtained principally from newspaper files, beginning with the *Arkansas Gazette* of November, 1819, the *Gazette and Democrat, Arkansas Banner, True Democrat, Arkansas Democrat, Washington Telegraph*, and other early newspapers. These files are being preserved by the Arkansas History Commission, Department of Archives and History. Acknowledgment is made of our indebtedness to Mr. Dallas T. Herndon, secretary of the commission, through whose assistance the preparation was made possible.

As the early records are almost wholly the observations of one of the early pioneers a word will be said of his coming to Arkansas. When the Territory was formed Arkansas Post, the seat of government, soon became a thriving village, and in 1819 among others there came to the Post a typical New England Yankee, Mr. William E. Woodruff, who founded the *Arkansas Gazette*, and it is to this untiring worker and close observer that we are indebted for our early records of Arkansas's weather. Mr. Woodruff's connection with the *Gazette* continued until the early fifties, and while he was actively engaged editing the paper scarcely a week passed without some note being made as to the prevailing weather, the river stage, and the crops.

Nature did her part toward giving the first Territorial Christmas a Christmas appearance, the weather being cold and rainy, accompanied with sleet and ice for several days preceding, and on the 24th snow covered the ground and continued the 25th.

In the early days supplies were received at the Post by boat from Cincinnati or New Orleans, much of the mail the same way; there was a post route through Davidsonville to the Post over which there was spasmodic service. This route, coming as it did through the northeastern section of the Territory, necessarily crossed many creeks and bayous, and after heavy rains there was always a wail going up from the *Gazette* that no mail was received, and when the river was too low for navigation the inconvenience caused thereby was commented on. Thus on February 12, 1820:

> Our supply of paper was not received, owing to the uncommonly low state of the river for several months past.

The spring of 1820 was a late one. In the issue of the 11th of March we find:

> On Monday night last we were visited with a heavy fall of rain and hail, accompanied with tremendous thunder and lightning, which was succeeded by sleet and snow on Tuesday morning. The storm did not cease until Wednesday morning, the snow then lying 5 inches deep on a level.

After March there were frequent rains, and boating continued good. As late in the year as December heavy rains occurred, causing considerable swell in the river, a rise of 8 to 10 feet being recorded one week.

The winter 1820–21 was a severe one.

> Accounts from all quarters agree. The present winter will stand preeminent in the annals of meteorology as the severest for 40 years, and even the hard one of 1780 must yield the palm to 1821. It is a remarkable fact hitherto unaccounted for by philosophers, that every fortieth year should be distinguished by the severity of its winters. Strikingly exemplifying this is 1740 and 1780, winters in which the cold was so intense that they are still referred to with chilling recollections as dreadful.

Traffic on the river continued throughout the summer, and while there was moderately high water on the Arkansas in July, no material damage to crops occurred. The season as a whole was very favorable for cotton and corn and the farmers reaped a rich reward in the fall, the crops being the most abundant thus far harvested in the Territory. The late autumn and early winter were dry, and by December it was necessary to reduce the size of the *Gazette* owing to a scarcity of paper, the river at that season being too low for boating.

The first snow came in November, and on the 24th the ground was covered to a depth of 1 inch. Winter set in early. Quoting from the first issue published at Little Rock, December 29, 1821:

> For some time past the weather has been extremely cold. On Sunday morning the Arkansas River was frozen over opposite this place, but broke up in a few hours; the drifting ice, however, commenced lodging a short distance above, and on Tuesday the river was so completely frozen and choked up that several persons crossed over on the ice with utmost safety. Others found good skating on the river, an amusement but little known in this country.

The first important rise in the river next spring came in May. *Gazette*, June 11:

> The Arkansas has been higher during the last seven or eight days than for several years past. The large rock at the lower end of this town was about 3 feet under water, a height which the river has not before attained since 1814.

(The height of the top of this rock, "Little Rock," from which the city takes its name, is 24.5 feet on the present gage.)

After this flood the season was average and nothing out of ordinary occurred. In October the river was again high, and heavy rains kept the watercourses full. The 1st of December brought winter and the first snow of the season. The temperature at sunrise of the 6th was 16° F. and rose only 1° during the day; by 10 p. m. it was 5° F. and at sunrise the morning of the 7th the mercury stood at 9° F. below zero and continued below until 10

o'clock in the morning; again the morning of the 18th the temperature was 3° F. below. The weather continued bad with roads near impassible most of the time during December, January, and February. On Monday, the 10th of February, the post rider from Batesville arrived opposite this place, but owing to the floating ice decided crossing too hazardous and returned to Batesville. Ice formed on both sides of the Arkansas, but owing to a high stage the river did not freeze over. The weather continued exceedingly cold throughout February with a minimum 11° F. below. A vast amount of stock died during the cold and at places the river bottoms were reported literally strewn with carcasses of cattle. Mail from Batesville was delayed many times by the cold and snow, and, as spring came on, by the overflowing streams.

A tornado occurred near the village of Little Rock on Wednesday night, May 7, 1823, the storm lasting an hour, during which time rain fell in torrents, accompanied by heavy thunder and strong wind, the largest trees of the forest being uprooted. No serious damage occurred in the village. In June, 1823, the Arkansas again went on a rampage, reaching a stage 13 inches higher than in June, 1822 (about 28.5 on our present gage).

The fall months being dry, conditions were very favorable for harvesting the crop, which, despite the high water in June, was abundant, especially the corn. Frost occurred the 23d of September, the earliest date of which we have a record at Little Rock. In November forest fires deluged the village with smoke, producing continued twilight several days.

Of the next two years, 1824 and 1825, we are able to learn very little, except that there was a flood on the White in 1824, and that during the summer of 1825 little boating was done on the Arkansas because of low water. The spring of 1826 was a late one, and in May the river again flooded, the crest being about 29.2 feet. July was hot and dry.

"If the failure of mail was due to high water, partiality is being shown to southern Missouri and the northern portion of this Territory," says Mr. Woodruff.

In September, the Arkansas reached a stage of 27 feet.

The winter of 1826–27 was very mild, peach trees blooming the last week in December. Excepting a short cold snap in January the temperature scarcely was freezing until in March, when a cold spell did some damage to fruit.

The growing season of 1827 was favorable for crops, except that the weather was rather dry during August. A wet fall was followed by another mild winter, peach trees blooming at Christmas. The only snow of the winter fell in February. A few days were cold during March, but the weather was generally moderate until April, when a severe cold wave, the coldest of the winter, damaged fruit and mast. This severe weather soon moderated and was followed by heavy rains, with high water on the Arkansas in May. In the southwestern counties the rains were much heavier, and Red River reached a stage of 7 or 8 feet above previous high-water marks.

The summer of 1828 was hot and dry. The partial drought which was broken in August damaged crops considerably, especially late corn. Temperatures as high as 90° F. continued until September, and the weather was very fine until the latter part of October, there being little rain until then.

Light frost occurred the 11th of October. November was clear and pleasant—very favorable for cotton picking, the first severe frost coming the 25th. Cold weather did not set in until January, 1829, gardens being green until about that time. The river was very low during the summer and fall of 1828 and did not reach a moderate stage until March, 1829.

The winter of 1828–29 was severely cold and the spring of 1829 was the most backward during 10 years. A 3-inch snow fell the latter part of March, and frost continued until May.

There were light showers but not enough to keep the river navigable and scarcely any rise occurred until fall. Despite the late spring, crops were unusually good in August, but in the fall heavy rains interfered with the harvest. Winter set in early. By the 20th of November a snowstorm gripped the Territory, and there was ice at Little Rock an inch thick. December was raw and disagreeable; but by January, 1830, spring apparently had come, and the second week found gardens green, the weather delightful, but the Arkansas fast reaching a stage too low for navigation. This was not for long, however, for in April it was again flowing bank full. Crops were planted by the 1st of May, the weather continuing warm and favorable.

Between 8 and 9 p. m., May 30, a tornado struck the village of Little Rock, uprooting trees, unroofing buildings and doing considerable damage. The storm moved from the southwest toward the northeast and was most destructive east of the village.

Crops were slightly damaged this season by dry weather in August. Corn and cotton were good but Irish potatoes, sweet potatoes, and turnips were short. In November the river was so low that it was forded every day at a point about 4 miles below town. No material rise occurred until March, 1831.

Cold weather set in the latter part of December, with rain and snow. Snow fell the first week in January, covering the muddy ground to a depth of 6 inches. Fifteen inches was reported in Washington County. The weather continued cold in March and the Arkansas had in it much floating ice, a condition which seldom occurs so late in the spring. While the spring was cool, crops made good progress. August 10 was so cold fires were necessary for comfort. In September heavy rains injured cotton. The wheat crop was good.

The winter of 1831–32 was colder than the average, with considerable snow and ice. The White at Batesville was frozen over in December and the Arkansas was frozen over 20 miles below Little Rock; at Batesville the river was again frozen over the 29th of February. By the latter part of March the weather had moderated and farming operations were making progress; peach trees were blooming. In May the Arkansas was again high, but did not flood, and by the 1st of July a severe drought was damaging crops considerably. Light frost occurred the 25th of September and some snow fell in November, the river continuing at a good boating stage.

The winter of 1832–33 was decidedly a mild one, outdoor work continuing, and little snow or cold weather was experienced.

June, 1833, brought another flood.

Plantations along the river are all under and scarcely an acre under cultivation has escaped. The damage is inestimable; hundreds of farmers and planters have lost everything. We have ascertained by actual measurement from a mark made by us 8 or 10 years ago that the river attained a greater height during the last rise by about 2 feet 6 inches than it has ever before attained within the recollection of our oldest inhabitants.

(In May, 1826, the crest was about 29.2 on our present gage, making this flood about 31.7 feet.) Crops in the lowlands were destroyed, but in the hills the yield was good.

November 13, 1833:

Last night we observed a great number of falling stars. Frequently a dozen could be seen at one time, many of them bright globes of fire, producing sufficient light to admit of reading the smallest print. They were in every quarter, flying in every direction. It was the most grand spectacle of the kind we ever witnessed. It was first noticed a little before 4 o'clock and continued until daybreak.

The Arkansas was again frozen over in January, 1834. While there was plenty of rain for farming operations throughout the spring, there was not enough to keep the river at a navigable stage. The summer was hot, cotton was never better, the corn crop abundant.

During the eclipse of the sun November 30, 1834, the sky was clear, not a cloud in sight, and one star was visible for an hour.

The winter of 1834–35 was colder than the average, the temperature being below zero in February 1835, and the river full of floating ice. Spring was very backward, the temperature reaching 50° F. only once before the 10th day of March. Crops were late but unusually fine. Considerable rain fell during the summer months and cotton suffered; corn did well enough, but fodder was not saved, owing to wet weather.

The winter 1835–36 was not severe, and in statehood year, 1836, peach trees were blooming in January. The river during the winter continued navigable, and in April, 1836, there was another flood almost as high as 1833. The exact stage is not recorded. In 1836 rainy weather during the summer and fall again damaged crops, the lowlands being flooded in September. By the 29th of November the ground was covered with snow 2 to 3 inches. On May 22, 1837, a severe hailstorm visited this section. The stones were not larger than musket balls, but fell so thick and fast that the ground was entirely covered.

As a crop year 1837 was all that could be desired. The corn yield was the best ever known and the cotton quality and quantity left nothing to be desired. The first frost of the fall occurred on the 24th of October.

The Arkansas was high in May, 1838. The spring was cool up to the middle of May and very unfavorable for farm work. This year crops were severely damaged by a continued drought, corn averaging not over half a crop. Reports from all over the State agree that the drought was the most disastrous ever experienced. In the fall the river was very low, and instead of muddy, as usual, was clear in consequence of no rain. Mr. Woodruff says that during his 20 years on the river he had never before seen the water so clear.

October 24, 1838:

The river continues low, bacon, flour, and provisions high. Unless we have rain and the river rises, Yankees may eat corn bread, as there is no flour or bacon for sale in Little Rock. The legislators will drink their toddy without sweetening.

Low water continued until January, when there was a temporary rise. In December a thin coat of ice covered the river. March brought a boating stage, which continued throughout the summer despite the dry weather of August. The season was average; nothing out of the ordinary was noted until the 27th of November, when a severe sleet and ice storm occurred, which destroyed fruit trees and did other damage, the temperature being 8° F.

The year 1840 was marked by high water in May, 26 feet on the present gage, and a tornado the 10th of June, during which torrential rain fell and considerable damage was done. The winter 1840–41 was mild and pleasant, the roads in February being reported in better condition than ever before at that season of the year. The weather continued mild, and cherries were ripe the 26th of May. Summer 1841 found the river very low and it continued so until October.

The winter 1841–42 was the mildest experienced in several years. Gardens were green and peach trees in bloom the 1st of February, the spring being about 20 days earlier than the preceding one. The 1st of April crops were well advanced and winter wheat was especially fine. April was cold and rainy, rather unfavorable for farming operations but frequent rains during the growing season and fine weather throughout the summer made crops prosper, and the 17th of October crops of every description were better than they were in 1837, the good crop year.

The winter 1842–43 was not unusually cold, but more snow fell than ever before noted. There were five snowstorms, the one of greatest depth occurring March 20, 1843, when the ground was covered 8 inches on a level. The dates were December 14, January 11, February 13 March 4, and March 20. An earthquake shock was noted in February and a bright mass of vapor rising to an angle of 40° was mentioned as observed between 7 and 8 o'clock on the evening of the 14th of March. From the description it must have been either the zodiacal light or the aurora. A comet is mentioned during March and April.

Nothing out of the ordinary was again recorded until the spring of 1844, when in May the river reached a stage of 32.6 feet, the highest on record. All crops in the lowlands were destroyed. This flood had no more than abated until heavy rains again put the water out in July. The exact stages are not given but the lowlands were all flooded along the Arkansas, and in Jackson County only the crops grown on the highlands matured.

The winter was mild. In February the weather was very pleasant, peach trees being in full bloom, willows green, forest buds bursting.

High water came again on the Arkansas in July, 1845, but there was no general destruction of crops as in 1844. Conway reported more cotton than could be gathered and enough corn to feed all the emigrants to Texas. The fall was very dry and favorable for harvesting, the river too low for navigation.

Gazette, December 3, 1845:

Winter is upon us. Last Friday the temperature fell to 15°, and snow began early Saturday night, continuing until Sunday night, when at least 8 inches had fallen. It now stands, Tuesday morning, after two days of bright sunshine, about 6 inches deep and the cold is intense. Our city is merry with the bells of gliding sleighs, and hot whisky punch is at a premium. Snow fell again Tuesday night but this, Wednesday morning, is clear and bright but very cold.

No material rise in the river occurred until the following spring, and then the boating period was short, the stage being low again in August and continuing so until the latter part of November.

In June, 1846, crops throughout the country were looking fine and promising showers fell about as needed, but they were held back somewhat by cold weather and a damaging wind storm the 3d of July destroyed some. Taking the year as a whole, the corn crop was considerably above an average, but cotton was not quite so good, having made too luxuriant a growth, and rain in the fall interfered with picking. September was very warm but in October the weather was more pleasant and favorable for harvesting. The first frost occurred the 23d of October.

The winter 1846–47 was mild. Mention of freezing temperature was found only four times. Rains kept the river at a moderate stage and farming operations went merrily on. By the 2d of July many were laying by

their corn. Randolph County reported crops better than ever before, and an excellent oat crop was harvested in Hempstead County. Worms did some damage to cotton in 1846 and were reported again in the Red River section in 1847, but little damage was done.

The year 1848 was unmarked except that there was no material rise in the Arkansas.

Gazette, November 24, 1848:

On Friday evening last the aurora borealis was observed. The whole northern horizon seemed brilliantly illuminated with a pale pink flame, extending at times to the zenith, presenting a grand display of this wonderful phenomenon.

December 8, 1848:

The weather is as wet as water can make it, walking as juicy as julep in June, but not so agreeable. During Tuesday night it rained incessantly, causing such a rise in that beautiful and neglected stream, the Town Branch, as to create considerable excitement among the residents and planks along its course.

The river remained navigable, the season average, with nothing out of the ordinary to report until the 18th of May, 1849, when heavy frost destroyed the greater portion of the cotton that was up. This frost was followed in a few days by a heavy rain and wind storm, doing considerable damage not only to crops but uprooting trees as well. In July almost incessant rains damaged crops still more; oats, which were just ready to cut the 6th, were injured considerably. Reports from all over the State indicate damage in all lowlands. The Arkansas was near flood stage; the Little Red at Searcy was almost as high as previous high-water mark, and from Red River there was a report of $1,000,000 damage. By September conditions were near normal, and the fall months were pleasant.

The winter 1849–50 was not recorded as severely cold at Little Rock, but at Mount Ida, Montgomery County, zero temperatures occurred in January. A 6-inch snow fell at Little Rock about the middle of February. Spring was late and very unfavorable for planting, and while crops were late in most sections of the State they were promising until dry weather in August did some damage. In the fall the turnout was better than expected. September was hot and dry. During the week ending September 27, 1850, the temperature reached 90° F. every day; and no rain having fallen for a month the river was very low, and remained so until January, 1851.

In the southern part of the State dry weather damaged crops considerably during the growing season of 1851, but in the White River bottoms more rain fell and the late crops were benefited. The Arkansas was low during the summer months, and while there were fluctuations, it being navigable at times, there was no material rise until the spring of 1852. In January, 1852, it was frozen over at Little Rock for a short time. Frost the latter days of March destroyed fruit. An aurora was observed Tuesday night, April 20, 1852. The Arkansas was full in May, but the damage was trifling, and the season as a whole was very favorable, more corn being made than during the two previous years. Cotton was damaged somewhat by wet weather in August. Potatoes were abundant.

The Arkansas was navigable during the winter 1852–53 and continued so until August, 1853. The winter was average, snow falling in February and March, but no severely cold weather was noted. The crop in 1853 was unusually fine, the fall being dry and favorable for harvesting. In October the river was "in fine boating order for birch canoes," nothing more, about this stage continuing until May, 1854

Considerable rain fell in June, 1854, and crops were damaged, but by August the weather was too dry for corn. Late showers improved conditions somewhat, but only a fair crop was made.

Through another winter, 1854–55, the river was too low for navigation except by the lightest vessels. No severe weather occurred and the season went from winter to summer without much spring. There was no rise in the river during the spring months, and planters made flatboats to carry their cotton to New Orleans. Showers fell about as needed but there was no rise in the river. Late rain damaged cotton considerably, some sections reporting the yield cut in half, but corn was good. Killing frost occurred the 26th of October, and as the river was low it froze over in January, 1856. In February there was a rise, and in March boating was flourishing.

The summer of 1856 was dry and crops were damaged; insects were more active than ever before. In the fall heavy rains did further damage. There were many good crops made, but more poor ones, so the year as a whole was not favorable. The river was low during the summer months, but became navigable for the larger class of boats late in the fall.

There was heavy snow in January, 1857, and the river was closed for over a week. In February, with a thaw came high water. In April snow and cold weather damaged fruit and vegetables. Corn had to be replanted this spring, and, while late, made a good yield. Owing to heavy rain in the fall, cotton was short.

The winter 1857–58 brought no unusual weather and the river remained navigable. In March, 1858, owing to heavy rains, all the rivers of the State were high. The Little Red at Searcy was very high, Jacksonport was entirely submerged by high water on the White and Black, and the Mississippi was high. The fall was wet, the cotton crop short, but corn production was above an average and fruit was very plentiful.

The winter 1858–59 was average, the river low most of the season and the spring of 1859 late. Cold weather in June damaged wheat in the northern part of the State, but despite a late spring an abundant crop was made and with a dry fall was harvested.

The river was low in December, but with January, 1860, came considerable rain and snow and higher water. The roads were impassable most of the time, the full streams making traveling almost impossible. Spring was again late and some damage occurred to crops in May, but as a whole the year was average and a fair crop was made.

For the next few years the papers were too full of secession and the war to make much mention of the weather or crops. From what is available we learn that as a crop year 1861 was a record breaker. The river was too low during the early summer for navigation, and except for a rise in August was low until February, 1862.

In 1862 there was a strong sentiment against raising cotton because the South could not dispose of it to any advantage, so principally food crops were grown.

Cold weather in the spring of 1862 damaged fruit, and a drought in July and August cut the corn and wheat crops short; but as an increased acreage had been devoted to grain, the supply was abundant for home consumption. In 1863 another large corn and wheat crop was made, and, while rust did some damage, the crop was larger than the previous year; fruit too was abundant. The *Washington Telegraph* says:

The starvation policy of the Federals will be defeated this year by the Almighty.

The winter of 1863–64 was severely cold. An Army train crossed White River on the ice at Jacksonport, and even in the southern part of the State, Washington, Hempstead County, the temperature was as low as 6° F. The early spring of 1864 was favorable, but cold weather about the middle of March damaged fruit. A fair corn and wheat crop was made.

In 1866 the spring was promising except too wet for cotton. Corn and vegetables were fine to begin with, but the wet weather continued so late into the summer that the crops in the bottoms were drowned out and in the hills were washed away. In the late summer and fall dry weather did further damage. The rivers were high most of the spring and early summer, but there was no general overflow.

The spring of 1867 was cold and wet, snow, sleet, and hail falling at Little Rock as late as the 5th of March. Owing to the wet weather crops were late and very grassy; but dry weather came in time to clean them, and an excellent corn and cotton crop was made. The fall was dry. The first bale of cotton was marketed the 24th of September, about a month later than the average date. The weather continued warm, with occasional temperatures as high as 80° F. until the middle of December, but the last week of the year it was severely cold, with plenty of sleet and snow on the ground.

The year 1868 was favorable and an excellent crop was made in most sections of the State. A wet fall was unfavorable for cotton picking. Winter did not set in until after Christmas.

The spring and summer of 1869 were average, but the fall was very dry and the Arkansas too low for navigation.

January, 1870, was a very pleasant month, more like autumn than winter, but the latter part of February was cold, the temperature at one time being 10° F., and the first 20 days of March were very cold. Spring was late, with snow on the ground Easter, April 16, 1870. After the spring rains the weather was dry and favorable for farm operations, and the best crop made since the war was harvested in the fall.

The winter of 1870–71 was not severely cold, but cool weather continued until in May; so the season was backward and some damage was done to wheat; but the year 1871 as a whole was favorable and a good crop was made.

The spring of 1872 was again backward. Cotton was not all planted until June, the result being that an increased acreage was given to corn. High water also delayed planting in the low lands. In May a terrific hailstorm was reported in Jefferson County, but other unfavorable conditions had prevented much headway being made with crops, so the damage was lighter than it would have been under normal conditions. As the season advanced conditions became more favorable and a fair crop was made, corn being good, and cotton being estimated at three-fourths a normal crop.

Of the winter 1872–73 little information was obtained, but the spring of 1873 was wet, and farmers were considerably behind with their work the middle of June. Wet weather continued and some cotton was never cleaned. Oats and pastures were good. Cotton was short, but the grain crops were sufficient for home consumption.

The year 1874 was unmarked, conditions being about average and a fair crop was harvested.

From 1875 to July, 1879, little definite information was obtained. There seemed to be nothing of marked importance, the weather being about normal and crops average, with no disastrous floods.

The Weather Bureau records starts the 1st of July, 1879, and thereafter the record is complete.

CONCLUSION.

It must not be inferred from this paper that Arkansas's climatic history is a record of floods, freezes, and droughts for those were events out of the ordinary and as such attracted attention and were mentioned in the newspapers, while of the average year little was said for abundant harvests and delightful seasons were not out of the ordinary.

Arkansas has an annual rainfall of 48 inches prop rly distributed for agricultural purposes, a growing season ranging from 169 days in the extreme northwest to 241 in the southern counties, permitting of the growing of two or more crops each year, heavy spring rains, warm summers, and long dry autumns. Situated as we are, far enough south to escape the prolonged and bitter cold of the northern winter, far enough north to avoid the scorching sun of a tropical summer, Arkansas's climate is admirable for a diversified agricultural State.

HAILSTORM AT LEHI, UTAH.

A hailstorm of unusual severity occurred at Lehi, northern Utah County, Utah, on August 9, 1920, from about 4:30 p. m. to 4:50 p. m., which, owing to the density of the population affected, was undoubtedly the most destructive hailstorm of record in the State. Other storms have deposited as much hail, and as large hailstones, within the State, but none has been so destructive of property.

The hailfall accompanied a moderate rain and thunder storm which passed over the city from Cedar Valley to the Wasatch Mountains, from which rain fell a few miles in all directions around Lehi, and a considerable amount of hail fell on the higher portion of the adjacent mountains. The path marked by the most destructive hail was about 1 mile wide and 2 miles long, extending in a northwest-southeast direction across the northern portion of Lehi city. An area about ¾ by 1¼ miles was well covered by intense hailfall, some local accumulations being a few inches deep.

The stones were unusually large, ranging from the size of large marbles to hens' eggs, the average size in a miscellaneous collection taken from the top of a drift after the storm being about 4 inches in circumference, though many were found to be from 5 to 6½ inches in circumference. They were mostly of a roughly spherical form, though many were flattened, elongated, or otherwise distorted. (Figs. 2 and 3.) Large numbers of the hailstones were broken by the impact of falling, and were found to have from 6 to 10 concentric layers of opaque and transparent snow and ice, covering a pellet of ice from a quarter to a half inch in diameter. At the Cooperative Weather Station (at the postoffice) 0.60 inch of precipitation was measured, about one-half of which was from melted hail. One stone picked up near the raingage after the storm was 6½ inches in circumference, though the station is slightly to one side of the path of greatest destruction.

The destruction of fruit, truck, gardens, potatoes, sugar beets, corn, unharvested grain, alfalfa and other crops was very great within the limited area mentioned, little being left worth harvesting excepting the tubers. Hundreds of chickens and some rabbits perished before they could reach shelter, and numerous horses and cattle, as well as several persons caught without shelter during the storm, suffered more or less bodily injury. Runaway teams destroyed considerable property about the city and in the adjacent agricultural fields, and composition roofs and automobile tops were riddled by the hailfall. Practically all the north windows within the central area of the storm and many of the west windows were broken; and the large greenhouses of the Lehi Floral Co., with their contents, were almost totally destroyed with the breaking of about 7,000 roof glass. (Fig. 3.) The total loss was estimated by Mr. Joseph Anderson, the cooperative weather observer, at about $50,000.—*J. Cecil Alter*, Meteorologist, Salt Lake City, Utah.

LIGHTNING PHOTOGRAPHS.

Mr. J. W. Stjernstedt, manager of the Pacific coast office of the American Transmarine Co. (Inc.), has furnished the Weather Bureau with two lightning photographs. These pictures were taken about 10 p. m. at Jamaica, Long Island, July 12, 1919. The storm was approaching from the east or northeast. Both pictures were made with a small kodak, using the F:45 stop. The two diagonal lines seen on fig. 1 J. W. S. near the upper left and lower right hand corners are defects in the negative. The white spots in the same picture are caused by falling raindrops illuminated by the lightning flash. Fig. 2 J. W. S. shows five successive flashes almost parallel; this is due to the wind movement, which carried forward the air through which the lightning was discharging.—*C. L. M.*

LIGHTNING INJURY IN A POTATO FIELD.

Articles have appeared from time to time in botanical literature describing lightning injury to plants. Such injuries to trees are of course quite common, but occasionally herbaceous plants growing in a level field are injured. The injured plants usually cover a more or less circular area of 10 to 30 feet in diameter.

A heavy electric storm occurred at College Park, Md., on August 9, between 6 and 6.30 p. m. A few days after this storm Mr. T. H. White, of the Agricultural Experiment Station, called the writer's attention to an area in one of his experimental potato plots that had apparently been struck by lightning. On the day following the storm the plants in this area were lying on the ground in a wilted condition, with stems somewhat twisted just above ground. This injured area of approximately 30 feet in diameter was staked off and no increase in its size has since been found. A 10-foot strip of grass separated this plot from an adjacent one and was partly included in the circular area, but no injury to the grass was noticed, although a few potato plants in the adjoining plot and just within the circular area were slightly injured. Fig. 1 E. S. J. (on plate opposite) was obtained 16 days after the storm and shows the area containing the dead plants.

All the conditions of the injury and the circumstances under which it occurred seem to be in good agreement, with the following explanation given by Jones and Gilbert:[1]

"When an electric storm breaks suddenly following a period of dry weather and the first rain wets the top soil, there remains a layer of dry earth between this wet surface and the moist soil underneath, which is a poor conductor of electricity. When the lightning strikes the wet surface soil it disperses in all directions, horizontally and then downward into the earth, following lines of least resistance. The plant stems and roots with their abundant water content are better conductors than the layer of dry soil just mentioned, and so the electric current passes through them. The tissues may thus be variously injured or killed, depending upon the amount of current passing through them. The strength of the current, of course, diminishes the farther it gets from the center of the affected spot, and consequently the lessened injury at the margins of the area."—*Earl S. Johnston*, Agricultural Experiment Station, University of Maryland.

STANDING WHEAT FIRED BY LIGHTNING.

On July 16, 1920, a field of standing wheat belonging to R. H. McKean and W. B. Rice, near Wasco, in Sherman County, Oreg., was set on fire by lightning, and about 200 acres were burned over. From such information as can be obtained it appears that the lightning struck in the open field, no buildings, trees, or fences being near. The storm was accompanied by high wind for a few minutes, and light rain fell. At Wasco, the nearest cooperative meteorological station, the rainfall on that date amounted to 0.10 inch.

While fires in ripe standing grain are very common in this section, the firing of standing grain by lightning direct is very unusual.—*Edward L. Wells.*

LIGHTNING AND FOREST FIRES.

Though forest fires caused by lightning are of frequent occurrence in California, the summer of 1920 will be recorded as one of the most disastrous in history. These summer thunderstorms are usually limited to the elevated portions of the State, which are densely forested. Lightning discharges are particularly dangerous, because, unlike eastern thunderstorms, these storms are usually accompanied by little or no rainfall, which might extinguish a fire once started.

The Forest Service announced that lightning caused 60 forest fires in northern California during the first five days of July. Again, as a result of a series of extremely violent thunderstorms which passed over the same region on August 4, approximately 240 forest fires were caused by lightning, according to the Forest Service. Again, on August 6, 35 forest fires were started by lightning in a single thunderstorm in the vicinity of Sisson, near Mount Shasta. During this storm lightning struck the forest lookout station on the summit of Mount Eddy, seriously injuring the ranger on duty there, and the lookout station was destroyed in the fire which followed. During the second week of August there were 7 extensive forest fires beyond control in northern California as a direct result of these storms. The forest-fire situation in northern California was the worst in four years. Because of deficient precipitation during the past rainy season, the forest floor was extremely dry, and fires spread with

[1] Jones, L. R., and W. W. Gilbert. Lightning injury to herbaceous plants. Phytopathology 8:270-282. 1918.

To face p. 452.

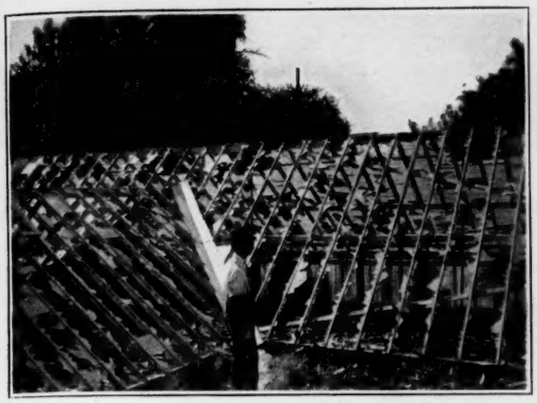

FIG. 1.—Lehi Floral Co.'s greenhouse, north slope (at right) and west slope (at left), after hailstorm of August 9, 1920. Photo by Zelda Kirkham, Lehi, Utah.

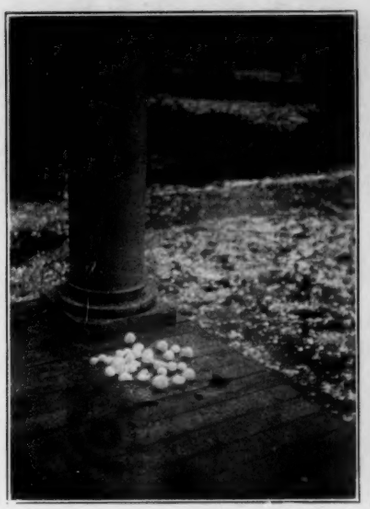

FIG. 2.—Hail gathered at random from adjacent yard, Lehi, Utah, August 9, 1920. The base plate of the porch post is 14 inches square and the flooring boards are 3½ inches wide. Note that many hailstones are broken. Photo by Zelda Kirkham, Lehi, Utah.

FIG. 3.—A hail drift, Lehi, Utah, August 9, 1920. The two stones on the pavement in the foreground were about as large as a guinea egg or a hen egg. Photo by Zelda Kirkham, Lehi Utah.

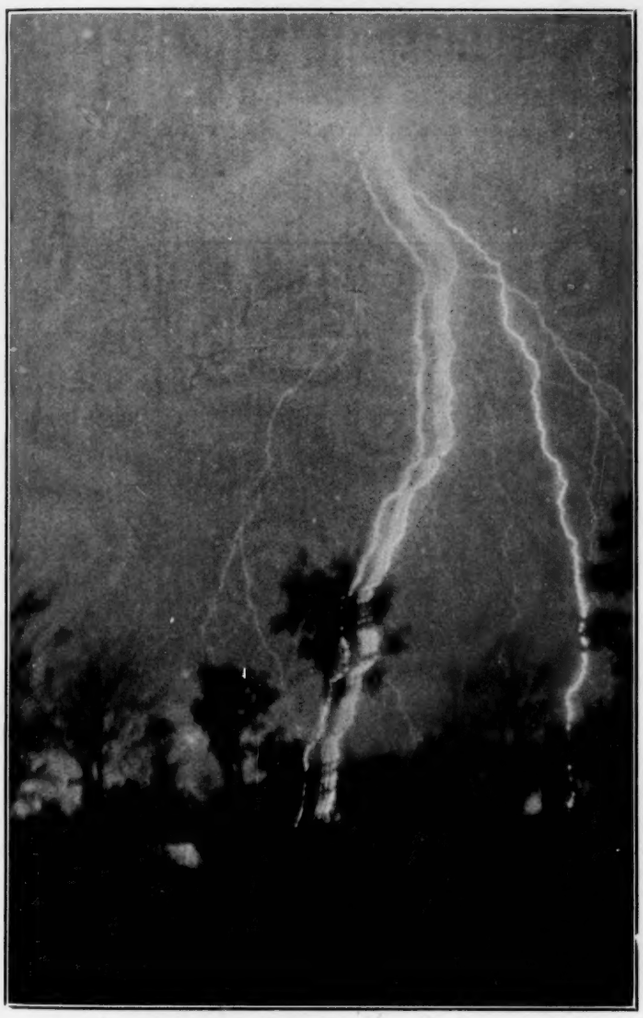

FIG. 2 J. W. S.—Lightning flashes at Jamaica, Long Island, about 10 p. m., July 12, 1919. Photo by J. W. Stjernstedt.

FIG. 1 J. W. S.—Lightning flash at Jamaica, Long Island, 10 p. m., July 12, 1919. Photo by J. W. Stjernstedt.

FIG. 1 E. S. J.—Area of potato field injured during the heavy electric storm of August 9, 1920, at College Park, Md., is indicated by the stakes.

FIG. 1 W. S. D.—Undulatory strato-cumulus, seen as gray and white rolls of cloud near noon on an overcast day late in May while a strong east wind was blowing. Taken looking south.

FIG. 2 W. S. D.—Strato-cumulus. A type often seen on windy afternoons, especially during the autumn, this study having been made in November while a northwest wind was blowing, at 3 p. m., lens being pointed southwest.

unprecedented rapidity. These fires continued to burn for about 10 days, when expert fire fighters were carried by aeroplane to strategic positions around the conflagrations. Cooler weather, accompanied by high relative humidity, aided the fighters in checking the fires. During six weeks the Forest Service expended $80,000 in combating forest fires in the national forests of California, most of them in the extreme northern portion of the State. If only 2 per cent of trees struck by lightning are ignited, as is stated in Forest Service Bulletin No. 111, there must have been a tremendous amount of electrical activity in the atmosphere over northern California during the summer of 1920.—*A. H. Palmer.*

A HOT SQUALL ON THE MAINE COAST.[1]

August 15, 1920, there was an unusual hot squall between 6 and 7 p. m. on the Maine coast at Ogunquit, York County, about 24 miles south of Portland, Me.

The weather had been peculiar for a week. On the coast there was a light east wind with cool air and much dense fog, while inland it was very hot and humid. Within observation from the beach great cumulo-nimbus clouds were observed every afternoon and heavy thunder was heard and lightning seen, but these disturbances on nearing the ocean were completely smothered by the cooler air. There was no rain on the ocean rim, but very heavy downpours fell inland only 20 miles, with severe lightning. And these disturbances invariably followed the rivers. The fishermen maintain that thunderstorms can not occur on the beach except at ebb tide, and this rule was not broken [nor verified]. For days the same localities got a drenching, while spots only a few miles away had not had a bit of rain for a month.

On August 15, at 6 p. m., the air on the beach was quite cool, about 62° F., with a light east wind. A heavy thunderstorm was visible about 20 miles north moving southeast. A black bank of clouds was observed coming from the north-northeast, and it rapidly approached, giving a blue-black sky. The clouds were mammato strato-cumulus, and on reaching the observer a moderately strong squall broke. The wind came from the northeast, from over the cold ocean, yet the temperature rose to 73° and it felt distinctly hot and very dry. The temperature remained at 73° for nearly an hour. The thunderstorm proper made off to sea in a southeasterly direction at some distance with a fine display of lightning. No rain fell on the beach, nor did the lightning get any nearer. Two days later, when a northeast wind of the same velocity was blowing, the temperature registered 58°. It seems as if this hot squall must have been a down-draft, differing from the usual cool squall possibly through having insufficient evaporating rain to keep the descending air cool.[2] The same kind of a squall in a milder form took place the next evening about the same time.—*R. M. Dole.*

[1] Cf. MONTHLY WEATHER REVIEW, Aug. 1919, 47: 566-567.

[2] See ibid., July, 1914, 42: 364; or *Jour. Franklin Inst.*, July, 1918, 186: 63-64 (W. J. Humphreys).

NOTES ON CLOUD PHOTOGRAPHY.[1]

By WILLIAM S. DAVIS.

[Orient, N. Y., May 25, 1920.]

The accompanying cloud studies were made at Orient, a village located upon the small peninsula forming the east end of the north fork of Long Island, N. Y. Because of the small land area in comparison with that of the surrounding waters of Long Island Sound, Gardners Bay, and Orient Harbor, the air currents at low elevations are less affected by local conditions upon the ground than would be the case in most sections, especially those removed from the coast.

In regard to the best method of photographing clouds, my experience leads me to advise the use of color-sensitive emulsions at all times, and in combination with a suitable ray filter when color is an important factor. If plates, rather than films, are employed the double-coated "nonhalation" variety will permit more latitude in exposure than the single-coated kind, though either can be used successfully if proper care is exercised to avoid overexposure upon delicate cloud forms.

When exposing on gray clouds there is little if anything to be gained by placing a ray filter on the lens, unless one is aiming to secure a good rendering of landscape at the same time. In this case, a filter generally helps to equalize tonal differences between sky and foreground sufficiently to allow of timing the exposure for the latter without loss of quality in the sky.

White clouds against a blue sky always call for the use of a ray filter to secure the best possible results, as is also the case when dealing with a brilliant sunset to better preserve the relative visual luminosity of the different colors. For general use a ray filter of moderate depth of yellow will be found sufficient, representative ones of this class being the Ingento series A, Cramer Isos II, and Wratten K1. To secure for study purposes the clearest rendering of very thin filmy clouds, such as certain types of cirrus, however, it is advisable to employ considerably stronger colored filters to emphasize the slight contrast between the clouds and sky. The same applies in the matter of preserving the luminous effect of deep yellow and orange tints in a gorgeous sunset sky. Here is where such a filter as the Ingento B (or the C series for still more contrast), Wratten K2 series, or Isos III will prove helpful.

When timing exposures for clouds alone, without regard to any land shown below, one-fourth the time usually allowed an open landscape will be found approximately correct for well-defined cloud masses, but very delicate white clouds would need still less comparative exposure, followed by longer time of development than usual in a solution well restrained with potassium bromide.

As a rough guide for a beginner, it may be stated that when using plates similar in speed to the Cramer "Inst. Iso" an exposure of one-fiftieth second without a ray filter would be close to the mark for bold masses of gray cloud in summer light, with the lens stopped to F. 16. Using the same sized stop, and a light yellow ray filter over the lens, from one-fifth to one-tenth second could be given upon white clouds in good sunlight, though a longer time could be allowed without harm when the tonal contrasts are well defined. All these exposures should be increased in early morning or near sunset, and in the weaker actinic light during the winter season.

[1] *See also* A. J. Henry: Cloud photography. MONTHLY WEATHER REVIEW, May, 1895, 23:169-171, 255. In this article the use of a liquid filter is described. See also for a cut of the apparatus as used *Scientific American* 72:137, March 2, 1895. The use of orthochromatic photographic plates, a developer strong in the reducing agent and highly restrained is recommended.

Much trouble from fogging of the negative by halation or sunshine entering the lens will be prevented by employing some kind of a lens shade to cut off all rays of light outside the view angle of the lens. This is especially important when working against the light.

APPARATUS AND METHODS FOR CLOUD PHOTOGRAPHY.

By ARTHUR J. WEED, Chief Instrument Maker.[1]

[Weather Bureau, Washington, July 24, 1920.]

SYNOPSIS.

The first requisite for cloud photography is a good camera with a very rigid support. To this equipment a ray filter or black mirror is a necessary adjunct in order to cut out the actinic light of the blue sky and render, in the finished print, white clouds on a dark background. Certain forms of clouds may be successfully photographed with a light bellows camera, but since many of the most interesting clouds are accompanied by high winds, a much more stable camera, such as the box type, on a permanent support is desirable. This should be so mounted as to cover the full sweep of the horizon and from the horizon to the zenith. The apparatus used at Mount Weather is fully described. Expensive apparatus is not necessary to attain excellent success in cloud photography.—*H. L.*

The first requisite in cloud photography is a good camera for that special purpose. Not necessarily an expensive apparatus, but one that is rigid and has the necessary means of attachment to a firm support.

A suitable ray filter, or black mirror, is necessary to cut out the actinic light of the blue sky and render, in the finished print, white clouds on a dark background just as we see them on a darker background of blue.

Excellent pictures may be made of certain types of clouds with a light bellows camera, when it is sheltered from the wind, but if one wishes to do really good work this will be found too light and shaky for the purpose, as some of our most interesting clouds occur only when a strong wind is blowing.

In order to get an unobstructed view, means should be provided for mounting the camera on the highest possible elevation like the top of a hill or the roof of a building.

Figure 1 (on plate facing p. 456) shows a camera built by the writer at Mount Weather Observatory. This was mounted on the roof of the Physical Laboratory.

Two permanent mountings were required for a full sweep of the horizon, each of which consisted of a piece of yellow pine timber 3 by 4 inches, the upper end turned to a diameter of about 3 inches. These turned portions of the posts were shellacked and when not in use were protected by metal covers made from pieces of tubing with a head soldered into one end.

The method of attaching the post to the metal railing is shown in figure 1.

The holder for the camera consisted of a tube to fit over the turned wood post, a frame to hold the bed of the camera, and two braces by which the vertical adjustments were made.

The tube was a piece of conduit pipe used to protect underground electric wires. To the top of the tube was secured a crosspiece of wood, and to this was hinged one end of the frame carrying the camera bed. To the other end of the frame two round metal braces were attached by hinges.

The tube was sawed open from the bottom for about one-half its length and a U-shaped strap of brass was placed around it. Through the free ends of this brass strap a bolt was inserted on which were two pairs of thick washers, each pair grooved to hold one of the metal braces of the frame. The bolt was provided with a large milled head nut. When this nut was tightened the camera was firmly secured both vertically and horizontally.

The frame was constructed so that the bed of the camera slid in between the two side rails where it was secured in position by four large-headed brass bolts provided with milled head nuts. The heads of these bolts gripped the edge of the camera bed.

This frame could be swung around on the post and had a vertical movement of 90°.

The construction of this portion of the apparatus can be seen in figure 1.

The camera consisted of a bed or frame, made from a piece of maple flooring, on which was mounted two wooden boxes painted a dead black on the inside and constructed of the proper size to telescope together readily.

The outer box was screwed to the camera bed and the front end of the inner box was secured to a maple frame having an L-shaped extension which was fitted to slide on the maple bed. This frame carried the lens board.

The arbitrary sizes to be followed in constructing such a camera are that the combined length of the two boxes

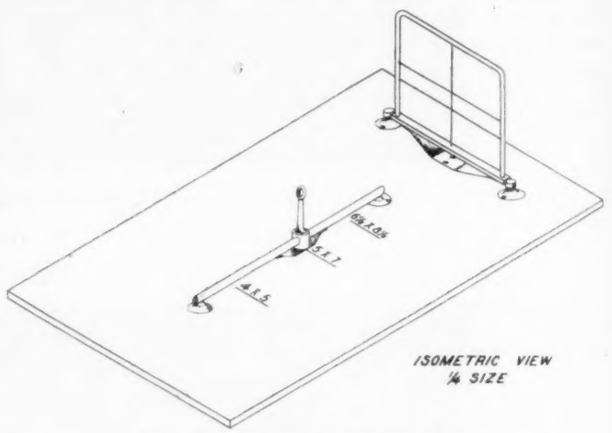

FIG. 2.—View finder for different sized pictures.

plus the lap where they slide together shall equal the focal length of the lens it is desired to use. Also the outer box must conform to the size of the plate holder used so that a light trap can be arranged.

In this particular camera a groove was made at the top and bottom of the rear end of the outer box a little wider than the thickness of the plate holder, and a flat spring was fastened in the outer edge of each groove which forced the plate holder against the end of the camera box.

The ground-glass focusing screen was mounted in a frame corresponding in size to the plate holder and had to be removed before inserting the holder. In figure 1 this frame and screen are shown in position.

When only one lens is to be used with such a camera the two boxes can be adjusted to get the proper focus of a distant object on the ground glass and then firmly secured to the bed at that point.

The only use for the focusing screen thereafter is to see just how much of the view will appear in the picture.

For quick work a special view finder was made and attached to the camera. This was in two parts, as shown in figure 2.

A rectangular frame proportional to the size of the plate to be used was mounted on the top of the camera box and had both a vertical and a horizontal wire

[1] Since Sept. 1, 1920, Mechanician, Rouss Physical Laboratory, University of Virginia.

stretched across it, meeting at the center. This frame was mounted so that it could be folded down onto the top of the camera and was retained in either position by a bent flat spring, the free ends of which pressed against the bottom or side of the frame.

Behind the frame, extending lengthwise of the camera, was a round rod mounted on supports at each end and having the underside flattened. Sliding on this rod was a vertical post with a small ring at the top to sight through. The center of this ring was level with the cross wires in the frame.

A spring attached to the lower end of the post and pressing up against the flattened portion of the rod held the post vertical. When not in use this post could be turned down on either side of the rod and out of the way.

The frame was in exact proportion to a 6½ by 8½ plate, that being the size of plate holder used with this camera.

The vertical post was adjusted to such a position on the rod that when one sighted through the ring all that was visible inside the frame would also be shown on the ground glass of the camera. This position was then marked on the top of the camera.

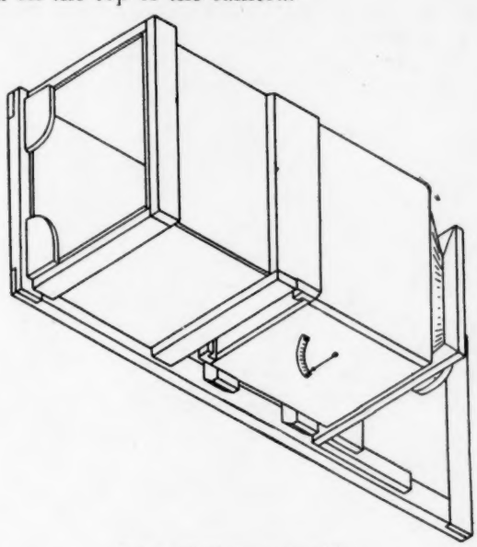

FIG. 3.—Cloud camera complete.

The dimensions of a 5 by 7 and a 4 by 5 plate were marked in pencil on the ground glass of the camera. The vertical post of the finder was then adjusted to show both these views approximately, and the corresponding positions of the post were marked on the camera.

This allowed the use of small plates in the 6½ by 8½ holders by using "kits," and the camera could be quickly sighted on a changing cloud, the finder showing just what would be included in the picture.

Figure 1 shows the camera as at first constructed, but considerable difficulty was experienced in using a focusing cloth on windy days. Another box was therefore constructed of light material corresponding in width and height to the outer box of the camera. This was of sufficient length to occupy the rear projection of the camera bed and proved to be a valuable acquisition, as, in addition to forming a focusing hood, it also supplied a location for the plate holders. A line drawing of the completed camera is shown in figure 3.

The back of this box was left open, except for two small pieces of thin wood set across the two lower corners. These retained the plate holders when the front of the camera was elevated to sight on a high cloud.

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On the side of the camera box was placed an inclinometer. This consisted of a short piece of fine brass wire having a loop bent in the upper end and a flat-pointed weight soldered to the lower end. A small brass screw was inserted through the loop and then screwed into the side of the camera box. The wire could swing free on the screw and the weight hang vertical.

The camera was then leveled and a brass sector, graduated from 0° to 90°, was placed in position, so that as the camera was tilted upward the angle from the horizon to which it was elevated would be indicated by the pointed end of the hanging weight. This should be boxed in and have a cover of glass or celluloid, otherwise it must be sheltered from the wind while the angle is being read.

In this branch of photography, as in all others, a good lens is to be desired. The lens used for most of the cloud pictures shown with this article was a Goerz 10½-inch Double Anastigmat, F.7.7, the property of Prof. A. J. Henry, who was then the Official in Charge at Mount Weather.

Occasionally a creditable cloud picture may be made with the lens alone. This applies particularly to the gray clouds. But for white clouds in a blue sky either a ray filter or black mirror must be used.

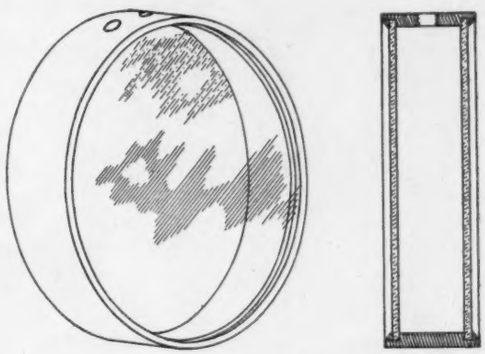

FIG. 4.—Details ray filter cell.

When the camera is pointed at the sky we see on the ground glass the white clouds on a darker background of blue sky; but when these same rays of light are allowed to fall on the ordinary sensitized plate the blue and violet rays from the sky are so much more actinic than the light rays reflected from the clouds that when the cloud has been properly exposed the sky is overexposed and, in consequence, the contrast between the blue and white is entirely lost, and the finished print shows only a bare patch of white for the sky.

If, however, a ray filter of the proper color is placed on the front of the lens, these intensely actinic rays of blue and violet are filtered out and the resulting print shows a white cloud on a dark background.

In practice the filter should be only sufficiently deep in color to give the required contract without unnecessarily increasing the length of the exposure.

The filter can be a colored liquid inclosed in a glass cell or a stained gelatine film mounted on glass or celluloid.

The first filters used on this camera were cells filled with colored liquid. These were made by using a fairly thick piece of brass tubing. A ring about ½ inch long was cut from the tube and either end bored out to form a recess for the glass plates as shown in figure 4.

Two holes were drilled in this ring and each tapped for a screw plug. These holes were for filling and cleaning the filter. A deposit will sometimes form on the inside surface of the glass plates which it is necessary to remove with a small tuft of cotton, held in a twisted loop of fine wire. If the filter is cleaned often enough a stream of water driven into one hole and escaping from the other will be sufficient to remove all deposits from the glass.

The two holes are placed as close together as possible, and in filling the cell one acts as a vent when the solution is introduced through the other.

The glass sides were made from lantern slide covers, which were selected so that there should be no spots or flaws in front of the leas. To cut the glass to the required size one was placed on a sheet of paper on which was drawn a circle the size of the recess in the brass ring. A glass cutter was used to square the lantern slide cover to the same dimensions as the diameter of the circle. Leaving the plate on the circle the corners can be cut off so that the plate is an octagon and if the cutter is in good condition the eight corners can be trimmed off leaving the glass nearly round.

The remainder of the fitting may be done with a sharp file wet with a solution of camphor dissolved in turpentine or the glass may be ground on a stone with water as a lubricant. In either case some care is required to prevent scratching the surface of the glass.

When the glasses have been fitted and cleaned they are placed in position and cemented with thick shellac. As soon as this hardens the cell is ready for use.

Potassium bichromate dissolved in water, and afterwards filtered makes an excellent solution for summer use. Distilled water should be used if possible, and the ingredients carefully measured so that in refilling the cell the same density of color will be obtained as in the original solution, and, in consequence, the same length of exposure required. The best method is to make up enough of the solution for several fillings and filter it into a bottle for future use. To prevent evaporation the cork should be dipped in melted paraffine before inserting in the bottle.

Where one wishes to obtain winter cloud pictures there is danger of this type of filter freezing. For this purpose a stained gelatine filter is best. Such a filter may be purchased from the larger supply houses or can be made up from a dry plate.

To construct a stained gelatine filter place an undeveloped dry plate, or lantern slide plate, in the hypo bath until the silver is all dissolved and the plate becomes clear. Wash out the hypo as with a regular fixed plate and it is ready for staining. If the plate is allowed to dry after washing it should be soaked up again just before staining.

For a yellow stain a few grains of picric acid dissolved in water may be used, but as this acid is rated as an explosive it is sometimes difficult to procure. Ammonium picrate may be substituted, or a good aniline dye used.

For dyeing gelatine filters the writer uses a deep but narrow tank so that the plate will stand vertically, or nearly so. The sides of the tank were made from two 4 x 5 dry plates from which the gelatine films had been removed. The two ends and bottom were made from strips of hard rubber with two grooves milled in them into which the glass plates were cemented as shown in figure 5.

The dye should be prepared and filtered to remove all particles which might settle on the soft gelatine surface and cause opaque spots.

Place the plate in the tank so that it tilts over to one side and the dye can be poured onto the glass side and not directly onto the gelatine film as it would make too deep a color at one spot. The film will take the color very quickly and should be removed from the tank immediately, rinsed and set up to dry.

In some instances it is desirable to show the landscape with the clouds. This requires a ray filter in which the color shades from a clear glass to the depth necessary for a cloud well up in the sky. This tank will be found well adapted for the making of such a filter.

Place sufficient dye in the tank to stand at a height of about ¾ inch. Lower the prepared plate into the dye and immediately run water into the tank until it overflows and the water runs away clear. On removing the plate it will be found that because of the gradual dilution of the dye in the tank the gelatine film will be shaded from a deep color at the bottom to clear glass at the top.

When the plate has been dried a section can be selected from which to cut the filter to suit the requirements.

The finished filter may be left in a square or rectangular shape or cut round in the same manner as previously described for the filter cell. Whatever the shape decided upon, a cover glass the same size and shape should be cut and the two cemented together with Canada balsam. This protects the gelatine film from injury.

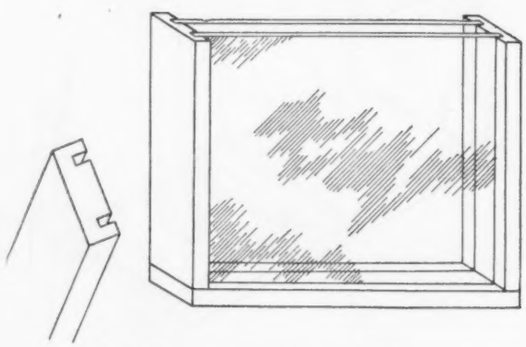

FIG. 5.—Tank for dyeing ray filters.

Provision must be made for holding the filter in front of the lens, either something to slip over the lens hood or by an independent mounting attached to the camera front. Whatever the means employed it is important that the back of the filter be shaded from the sun so that no reflected light can enter the lens.

On completion of a filter it is necessary to time it for the proper exposure, which can be accomplished by the sacrifice of one plate. From an exposure meter get the normal time of exposure required for the stop which it is desired to use, time of day, etc. Draw the plate holder slide a short distance and make an exposure corresponding to the above data. Draw the slide a little farther and make the same exposure. Continue this until the slide is entirely withdrawn.

When this plate is developed its density will be divided into strips, or sections, corresponding to the withdrawals of the plate holder slide. The last section exposed will have had *one* normal exposure and will be underexposed, for the filter will have cut down the amount of light which entered the lens. The previous section will have had *two* normal exposures and, in consequence, will show increased density and strength. The next section will give the result of *three* normal exposures, the next one *four*, etc.

To face p. 456.

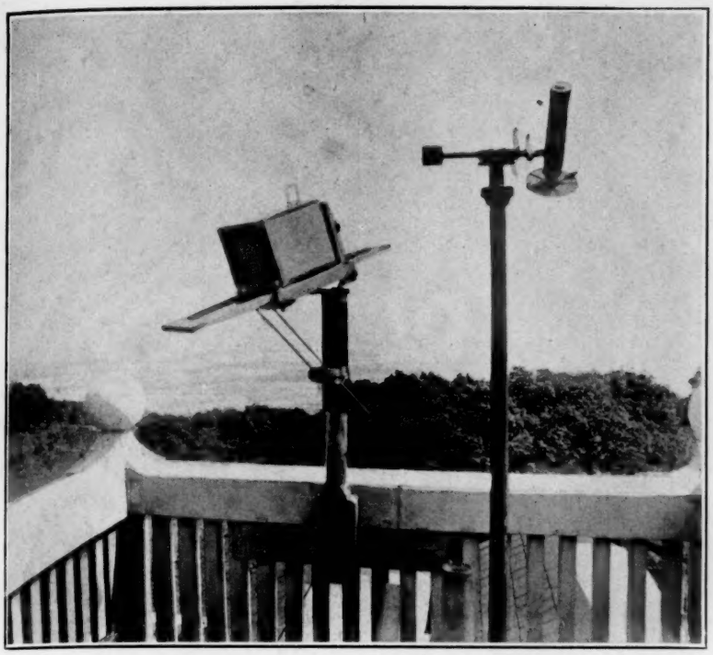

FIG. 1.—Cloud camera (on right) used at Mount Weather and Pickering polarimeter (on left).

FIG. 7.—Distant lightning on "Polychrome" plate.

FIG. 6.—Print from test plate for timing ray filters.

FIG. 8.—Thunderstorm in Shenandoah Valley, distant 25 miles.

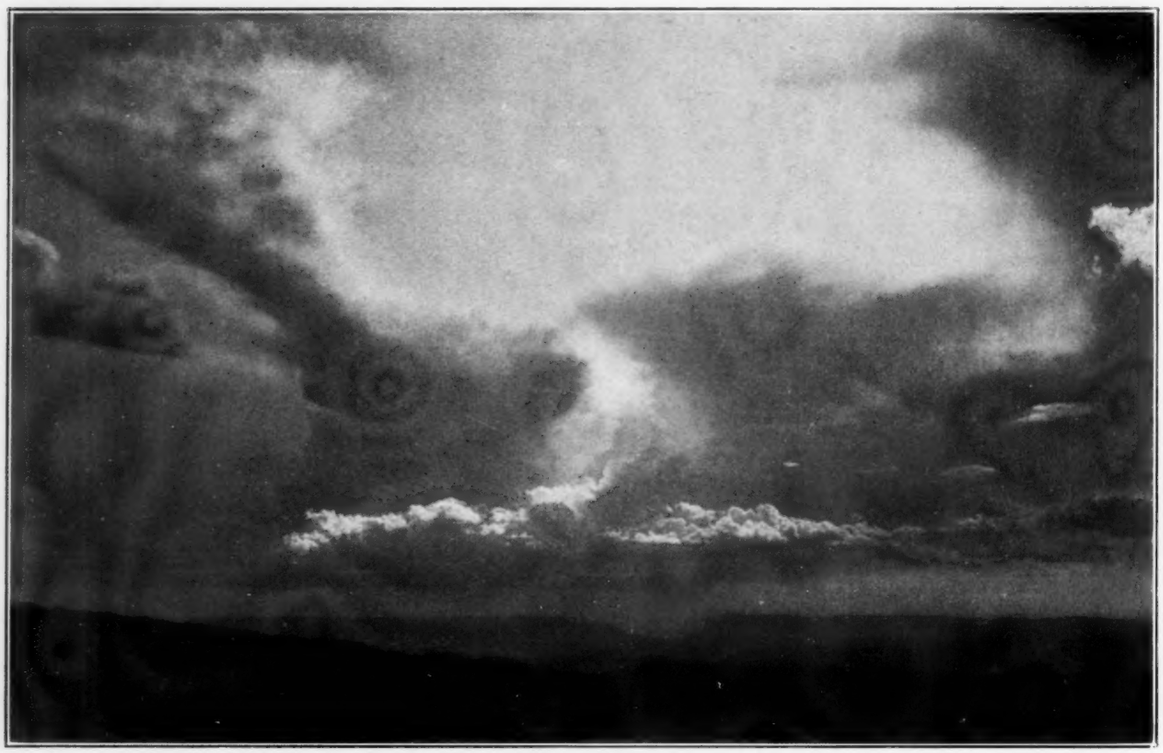

FIG. 9.—Same as Fig. 8, ten minutes later.

Suppose the third section of the negative is found to have the required printing qualities—the filter should be marked "3T," meaning "3 times," and whenever this particular filter is used it is only necessary to multiply the normal exposure given by the exposure meter three times to give the time of exposure necessary to produce the desired density of negative. Figure 6 shows a print from such a test negative.

For photographing the minute details of high cirrus clouds a black mirror is superior to a ray filter. The mirror must be mounted in such a manner that its reflecting surface stands at an angle of 33° with the axis of the lens. In this position the rays of light which come from the blue of the sky are partially polarized and are not reflected by the mirror, while the white light from the clouds is reflected very clearly.

The mirror must be a black, or very dark, glass, as an ordinary piece of clear glass blackened on the back with pigments while seeming perfect to the eye will, in nearly all cases, give a double image through the lens. One reflection from the front surface of the glass and a second reflection from the back take place. This gives the cloud a blurred outline on the negative.

In a recent publication, the name of which the writer can not recall, it was stated that if the back surface of a piece of clear glass were roughened or ground coarse before painting it black, this double reflection would be eliminated. This is passed along as an experiment worth trying, for a good black mirror is expensive.

One objection to the use of a mirror in cloud photography is that the reflection reverses the sky in the finished print. At Mount Weather another camera was constructed on a more elaborate scale for cloud work than the one here described. This was fitted with a real black-glass mirror and means were devised for obviating the reversal of the sky, but there was no opportunity to try it out before the closing of that Observatory.

The plates used for most of the pictures made at Mount Weather were "Standard Orthonon." These were found to give excellent results on white clouds but for clouds lighted up in color at sunrise and sunset "Standard Polychrome" plates were to be preferred. This latter plate was found to be well adapted for lightning pictures, being sensitive to red and yellow.

One night two "Orthonon" plates were exposed in succession on a receding storm. The third and last plate exposed was a "Polychrome," and as the storm was at that time several miles distant the lens was allowed to remain open until the lightning ceased. When developed the two "Orthonon" plates showed nothing, while on the "Polychrome" every flash was seen. This picture is reproduced in figure 7. In the original the contour of Bull Run Mountains can be seen, behind which the lightning was descending. This range of mountains is 20 miles distant from Mount Weather.

A rubber stamp was used for imprinting data slips similar to the following:

	Name	
No.		
Date	Time	
Direction	Angle	Filter
Lens	Stop	Exp.
Plate	Dev.	Formula
Print	Time	Dist.

As the plate holders were loaded in the dark room one of these slips of paper was marked with the number corresponding to that on the plate holder and the name of the plate therein. One slip was used for each plate.

When the loaded plate holders were placed in the receptacle at the back of the camera these slips were inserted under a spring clip just above them.

After exposing a plate in the camera its slip was filled out with the name of the cloud, date, time of day, direction by compass, angle in degrees from the horizon, as shown by the inclinometer, ray filter used, lens, stop and length of exposure.

These data slips were taken to the dark room with the plate holders, and after development the plates were filed away in negative envelopes as preservers, imprinted by the same rubber stamp with the above data filled in, together with the name of the developer and its formula number.

The envelope was marked with the serial number of the negative, which number was also scratched in the upper corner of the film to prevent its being misplaced in printing.

When prints were made, the paper used, time of printing, and distance from the light were added under their proper heading. This data adds very materially to the value of one's negatives.

As to a developer, every one has his favorite formula. some workers claim that the long feathery lines of the cirrus are only properly brought out with hydrochinone, but if the exposure is correct there is little choice in developing agents.

Giving the right exposure means having a fast lens, and a filter only sufficiently colored to cut out the blue and adding as little as possible to the time. This is particularly necessary on a fast-moving cloud having fine detail on its edges.

Since this cloud work was done at Mount Weather the Bureau of Standards has conducted a series of experiments on plates and filters for this class of work. They state that the best plate for sensitivity in red is the "Ilford Panchromatic" and a good plate for the same is the "Cramer Spectrum Process."

For a commercial ray filter they recommend "Wratten's Minus Blue," or "Kramer Isochromatic, medium-rapid, double.coated minus blue."

In preparing this article it has been the aim to deal more with the how and why of cloud photography than the treatment of the subject from a meteorological standpoint.

The apparatus described was made up of cheap material which could be acquired in an isolated location, yet it worked very successfully. It is not expected that the directions and suggestions here given will be followed implicitly, but that each worker will, as in this case, adapt means to ends.

In this work there is a psychological moment in which to "get your cloud" (compare figs. 8 and 9), but, unfortunately, the game has to be played under the rules of "catch-as-catch-can." It therefore behooves the worker to be always ready. The cloud camera at Mount Weather was located just under the rafters beside the stairway to the roof, with plate holders loaded, yet many a hurried trip was made from the main floor to the roof only to find that the opportunity for a successful picture had passed.

Aside from its meteorological value the work has all the fascination of hunting big game without its attendant danger, and there is no "closed season." You will learn what to hunt for in April; what in October.

A cumulus cloud is easy to get, but how many really good photos have you seen of change cirrus, mammato-cumulus, or scarf cloud? These are a few samples of the big game which it pays to go after, and to be able to exhibit a good specimen picture of such a cloud will be found as satisfactory as the showing of a pair of antlers.

PHOTOGRAPHY OF CLOUDS.

By C. J. P. CAVE.

[Excerpt from "The forms of clouds," Quart. Jour. Roy. Meteorological Soc., 1917, 43: 61-82. (From pp. 80-81.)]

The photography of clouds affords a subject of much interest. There is some difficulty in getting the exposure right until the photographer is somewhat experienced. As a general rule very short exposures are necessary. Clayden says that he has found very slow plates the best for the purpose, with no color screen. My own experience is that panchromatic plates and color screens give the most satisfactory results. I use a moderately deep yellow screen for all clouds except cirrus, but for cirrus I think a red screen is the best. When using color screens the exposure must be lengthened more in proportion than if one were taking ordinary subjects such as landscapes.

Stereoscopic photographs of clouds may be taken by having two cameras at some distance apart and taking two photographs simultaneously; the two cameras must be a quarter of a mile or so apart, except for clouds that are very near the observer. There is another way in which such photographs may be taken which I have not seen described before. If a cloud is moving, two photographs may be taken in succession from the same place, the resulting photographs showing a stereoscopic effect. Unless the clouds are moving very slowly it is advisable to take the two photographs as quickly as possible. Those shown (fig. 27 [not reproduced here]) were taken with an interval of abour 20 seconds. The clouds must be taken when they are moving in a direction at right angles to the line from the cloud to the observer. Of course different parts of the cloud may be moving with different velocities, and in this case the stereoscopic effect will not be true. In figure 27 [not reproduced here] it will be seen that there are about six different distances to be seen at the left-hand top corner of the picture. In the case of cloud sheets which are moving fast I have generally found that the stereoscopic effect is exaggerated and the sheet looks as though it were very low down. The chief difficulty in this way of taking stereographic photographs of clouds is that the form of the clouds changes even in the short interval between the two exposures.

CLOUD PHOTOGRAPHY.

[Reprinted from Scientific American Supplement, New York, Mar. 3, 1918, 163.]

A method recommended for cloud photography consists in the use of a device made up of a mirror of black glass mounted in a special frame and placed in front of the camera lens, so that the photograph will be taken from the mirror and the brilliant light of the clouds will be thus diminished. However, it is difficult to procure such black glass mirrors in ordinary trade, but it is comparatively easy to make a suitable mirror. This is done by taking a piece of clear glass such as is used for making mirrors and roughening one side after the manner of ground glass. On this latter side is applied a coating of black varnish made of Judaea bitumen. This avoids the double reflection which would be produced by using ordinary glass and simply putting on a coat of varnish. The time of exposure is, of course, much longer than in the usual way and may be from one-fifth to one twenty-fifth second when well stopped down. It is claimed that this arrangement allows of obtaining details of clouds which can not be had otherwise by the most improved plates and screens.

CUMULUS CLOUD OVER FIRE.

By OTTO NEUMER.

On September 13, about 4.30 p. m. (seventy-fifth meridian time) I was approaching New York City on a train, and, when between Rahway and Elizabeth, N. J., I observed a heavy black cloud in the direction of New York City. The cloud, I discovered later, was a smoke cloud and was hanging over New York Bay. The fire, which caused the great volume of smoke was in the Borough of Queens, just across the East River from Manhattan. The smoke rose almost vertically until it reached a height of about 1,500 meters, then passed off apparently horizontally to the southeast or south under the influence of a moderate or strong wind at that altitude. This wall of dense smoke extended from its origin in Queens as far as one could see toward the south. Directly in line with what seemed to be New York Bay, the smoke cloud was capped by a small puff of white—a small cumulus cloud. The formation seemed to be 400 or 500 meters long and very shallow. I do not think it lasted long, although I was unable to observe it longer than 10 minutes. There were no other clouds visible at the time.

NOTE.—The surface meteorological conditions at the New York Weather Bureau, at 4.30 were as follows: Temperature 21.7° C.; wind NW., 8.9 meters per second; dewpoint (noon) 7.8° C. Substituting these values in the equation for the height of the base of the cloud,[1] we obtain 1,800 meters, which is quite in accord with non-instrumental observations of Mr. Neumer.—*C. L. M.*

METEOROLOGICAL ASPECTS OF A MUNITION-DUMP EXPLOSION AT KIEV, JUNE 6, 1918.

By Dr. FRIEDRICH NOWOTNY.

[Abstracted from *Meteorologische Zeitschrift*, Mar.-Apr., 1920, pp. 67-73.]

At 10 a. m., June 6, 1918, about 11,000 tons of explosives stored at the munition depot of Zwierniec, a suburb of Kiev, were exploded from a fire which started in a bomb factory. The magnitude of the disaster may be surmised from the fact that at least 200 were killed and over 1,000 injured. The town of Zwierniec was almost completely destroyed through the agency of fire and air pressure. Other towns 6 and 8 kilometers distant were badly shaken and much property was destroyed. The meteorological conditions on the day in question were carefully observed both at the Austro-Hungarian meteorological station in that vicinity and by the author.

At the time of the catastrophe the sky was about seven-tenths covered with cumuli, whose bases were at about 1,300 meters elevation. The explosions sent dense masses of black smoke into the air, probably reaching an elevation of 3,600 meters, although the great mass of smoke reached the height of 3,200 meters. The clouds

[1] See "Heights of cumulus clouds forming over fires." MONTHLY WEATHER REVIEW, March, 1919, 147-149.

were moving slowly from the northwest, but the explosion served to tear the clouds apart and create an opening directly above. (* * * "*es bildete sich plötzlich ein Loch in der cu-Decke.*") After a while the slow southeastward motion was resumed. A light rain fell on the opposite side of the Dnieper River from the mass of cloud formed at the top of the smoke column.

A phenomenon, which has been observed on several occasions in the case of explosions in the craters of volcanoes[1] was the visibility of the spherically emanating pressure wave against the dark smoke cloud above.

After noon, the vigorous building up of cumuli over the fire had subsided somewhat, but the fact that there continued all through the afternoon fires and minor detonations had considerable influence upon the local wind and actually formed over that region a small low-pressure area. The possibility of the formation of such a small low-pressure area was investigated by calculating the probable amount of heat liberated by the explosions and the burning buildings in comparison with the amount of insolation received over this area. Assuming that 224,000 kg. of explosive materials were involved, it is found that about 160 x 10^7 kg. calories were liberated. This computation is based on other studies on explosive temperatures and the fact that 7 kg. of trinitrotoluol will liberate about 5,000 kg. calories. Other methods of approaching the computation, yield 298 x 10^7 kg. calories. and 211 x 10^7, respectively. The mean of all determinations gives 228 x 10^7 kg. calories. From the burning houses, it is estimated 42 x 10^7 kg. calories were liberated. From the sun, insolation equivalent to 104 x 10^7 kg. calories was received. This gives a total of 374 x 10^7 kg. calories which is more than would be received with a cloudless sky. The area considered was 3 sq. km.

The wind as observed at the Kiev observatory, the Austro-Hungarian station, and the German station, both at the surface and aloft, seem to bear out the point that a weak LOW was formed in this vicinity. Unfortunately, observations from the opposite side of the Dnieper are lacking. Pilot balloon observations at the German station (a few kilometers west of the explosion) showed before the catastrophe a west wind at the surface, becoming west-northwest up to the base of the clouds. The velocities varied from 5 to 14 meters per second. Six hours after the explosion the winds were as follows:

Height.	Direction.	Speed.
M.		*M. sec.*
Surface	NW.	4
100	WSW.	3
230	NE.	9
350	NNW.	4
460	NNW.	5
Above 700 to 3,000.	NW.	5-8

This, combined with the very slight evidence afforded by the barographs, seems to indicate that there was a slight depression formed about the fire.

As to the distances at which the detonations were heard, the author remarks that explosions of one kind and another were so frequent and common in that vicinity that accurate data, such as concerns the "zone of silence," etc., are lacking.

The bearing of such disturbances upon rainfall and its artificial production are logical questions, and the author inclines to the belief that disturbances of this magnitude may result in the production of light rain.[a] But such explosions are neither economical nor practical, and, in general, a drought would be quite as welcome.—*C. L. M.*

[1] Cf. "The visibility of sound waves," by F. A. Perret, *L'Astronomie*, May, 1919, pp. 193-196. Abstract in MONTHLY WEATHER REVIEW, March, 1920, 48: 162-163.

[a] Cf. Espy, James P., Rain from cumulus clouds over fires. MONTHLY WEATHER REVIEW, March, 1919, 47: 145-147.

TABLES OF SUNSPOT FREQUENCY FOR THE YEARS 1902-1919.[1]

By A. WOLFER.

[Zurich, Switzerland, Aug. 15, 1920.]

SYNOPSIS.

This article presents tables of observed and smoothed sunspot numbers which will serve as a continuation to those previously published, carrying them up to the end of 1919.

A discussion of the epochs of maxima and minima from 1610 to the maximum of 1917 results in a revision of the length of the sunspot period from 11.12 years to 11.2.

The revised edition of the Wolf Tables of Sunspot Frequency for the years 1749 to 1900, which were published in 1902 in *Astronomische Mitteilungen* No. 93, and also in the MONTHLY WEATHER REVIEW for April, 1902, has been followed by two supplementary editions, the first of which appeared in 1913 in the *Bulletin of the Mount Weather Observatory*[2] and the second in 1915 in the *Meteorologische Zeitschrift*.[3] The first included the years 1901–1912; the second, 1902–1914. A request from the editor of the MONTHLY WEATHER REVIEW has resulted in the preparation of a third edition in the same form as that of 1902 and including the period beginning in 1901 and ending with 1919.

Table 1 gives the definitive monthly means of the observed daily sunspot relative numbers which one may find published year by year by the Zurich Observatory in the *Astronomische Mitteilungen*. These means are based, without exception, upon careful daily observations, in which one and the same instrument has been employed at the Zurich Observatory on from 270 to 300 days of the year, so that there is not a single day whose value does not rest upon a real observation. As is known from the *Astronomische Mitteilungen*, these observations are supplemented by foreign observations made with different instruments and by different observers, and these are rendered comparable with our own by means of empirically determined reduction factors. Hence, all of the daily spot relative numbers are combined and published in a completely unified system. The monthly means given in Table 1 are followed in the last column by the yearly means and the maxima and minima denoting the 11-year period are made conspicuous by boldface type and italics, respectively.

[1] Translated by C. Le Roy Meisinger.

[2] Vol. 5, pt. 6, p. 365.

[3] Pp. 193–195.

TABLE 1.—*Monthly means of observed sunspot relative numbers.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1901	0.2	2.4	4.5	0.0	10 2	5.8	0.7	1.0	0.6	3.7	3.8	0.0	2.7
1902	5.2	0.0	12.4	0.0	2.8	1.4	0.9	2.3	7.6	16.3	10.3	1.1	5.0
1903	8.3	17.0	13.5	26.1	14.6	16.3	27.9	28.8	11.1	38.9	44.5	45.6	24.4
1904	31.6	24.5	37.2	43.0	39.5	41.9	50.6	58.2	30.1	54.2	38.0	54.6	42.0
1905	54.8	85.8	56.5	39 3	48.0	49.0	73.0	58.8	55.0	78.7	**107.2**	55.5	**63.5**
1906	45.5	31.3	64.5	55 3	57.7	63.2	103 3	47.7	56.1	17.8	38.9	64.7	53.8
1907	76.4	**108.2**	60.7	52.6	43.0	40.4	49.7	54.3	85.0	65.4	61.5	47.3	**62.0**
1908	39.2	33.9	28.7	57.6	40.8	48.1	39.5	90.5	86.9	32.3	45.5	39.5	48.5
1909	56.7	46.6	66.3	32.3	36.0	22.6	35.8	23.1	38.8	58.4	55.8	54.2	43.9
1910	26.4	31.5	21.4	8.4	22.2	12.3	14.1	11.5	26.2	38.3	4.9	5.8	18.6
1911	3.4	9.0	7.8	16.5	9.0	2.2	3.5	4.0	4.0	2.6	4.2	2 2	5.7
1912	0.3	*0.0*	4.9	4.5	4.4	4.1	3.0	0.3	9.5	4.6	1.1	6.4	3.6
1913	2.3	2.9	0.5	0.9	*0.0*	*0.0*	1.7	0.2	1.2	3.1	0.7	3.8	*1.4*
1914	2.8	2.6	3.1	17.3	5.2	11.4	5.4	7.7	12.7	8.2	16.4	22.3	9.6
1915	23.0	42.3	38.8	41.3	33.0	68.8	71.6	69.6	49.5	53.5	42.5	34.5	47.4
1916	45.3	55.4	67.0	71.8	74.5	67.7	53.5	35 2	45.1	50.7	65.6	53 0	55.4
1917	74.7	71.9	94.8	74.7	114.1	114.9	119.8	**154.5**	129.4	72.2	96.4	129.3	**103.9**
1918	96.0	65 3	72.2	80.5	76.7	59.4	107.6	101.7	79.9	85.0	83.4	59.2	80.6
1919	48.1	79.5	66.5	51.8	88.1	111.2	64.7	69.0	54.7	52.8	42.0	34.9	63.6

Table 2 contains the so-called "smoothed" monthly means of relative numbers which show the *mean* march of spot frequency through the 11-year period freed from the secondary short-period variations. Concerning the manner of their calculation from the "observed" monthly numbers, it is necessary to see the MONTHLY WEATHER REVIEW [4] or the *Bulletin of the Mount Weather Observatory*.[5] It is sufficient here merely to refer to these articles. The method of adjustment is so successful that short-period variations—those within a year—seem pretty completely to disappear. For investigations concerning the general long-period variations of sunspot phenomena, these values offer as practical a basis as the direct observations. Especially valuable are the smoothed values in determinations of the maxima and minima of the 11-year period, because with the observed values there is sometimes considerable doubt as to the correct epoch owing to the presence in the vicinity of a principal maximum or minimum of a large secondary maximum or minimum; this uncertainty disappears as a rule in the smoothed numbers, hence they are of greater value in determining the epochs. The maximum and minimum values of the smoothed monthly relative numbers are shown in Table 2 in bold-faced type and italic, respectively.

TABLE 2.—*Smoothed monthly means of sunspot relative numbers.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1901	4.8	4.4	3.9	3.2	*2.8*	*2.8*	3.0	3.1	3.3	3.6	3.3	*2.8*	*3.4*
1902	*2.6*	*2.7*	3.1	3.9	4.7	5.0	5.2	6.0	6.8	7.9	9.5	10.6	5.7
1903	12.3	14.6	15.8	16.9	19.3	22.5	25.4	26.6	27.9	29.6	31.4	33.5	23.0
1904	35.5	37.7	39.7	41.1	41.5	41.6	42.9	46.4	49.8	50.5	50.7	51.3	44.1
1905	52.5	53.5	54.6	56.6	60.5	63.4	63.1	60.4	58.5	59.5	60.6	61.6	58.7
1906	63.4	**64.2**	63.8	61.3	55.9	53.5	55.1	59.6	62.7	62.4	61.7	60.1	**60.3**
1907	56.9	55.0	56.4	59.6	62.6	62.8	60.5	55 9	51.4	50.3	50.4	50.6	56.0
1908	50.5	51.6	53.2	51.9	49.9	48.9	49.3	50.5	52.6	53.1	51.9	50.6	51.2
1909	49.4	46.4	41.6	40.7	42.2	43.3	42.6	40.7	38.2	35.4	33.8	32.8	40.6
1910	31.5	30.1	29.1	27.7	24.7	20.6	17.6	15.7	14.2	14.6	13.8	12.8	21.0
1911	12.0	11.2	10.0	7.6	6.0	5.9	5.6	5.1	4.6	4.0	3.3	3.2	6.5
1912	3.2	3.0	3.1	3.4	3.4	3.4	3.7	3.9	3.8	3.5	3.2	2.8	3.4
1913	2.6	2.5	2.2	1.8	1.7	1.6	*1.5*	*1.5*	1.6	2.4	3.3	4.0	*2.2*
1914	4.6	5.1	5.8	6.5	7.4	8.8	10.4	12.9	16.1	18.6	20.7	24.3	11.8
1915	29.4	34.8	38.9	42.3	45.3	46.9	48.3	49.8	51.5	53.9	56.9	58.6	46.4
1916	57.8	55.6	54.0	53.7	54.6	56.3	58.3	60.2	62.1	63.3	65.1	68.7	59.1
1917	73.4	81.2	89.7	94.1	96.3	100.7	104.8	**105.4**	104.2	103.5	102.2	98.3	**96.2**
1918	95.5	92.8	88.5	87.0	87.0	83.5	78.6	77.2	77.5	76.1	75.4	78.0	83.1
1919	78.4	75.2	72.8	70.4	67.4	64.6	.....	.....	.....	.....	.....	.....	.....

A table of the epochs of maxima and minima from 1610 to 1901 was published in the earlier article in the MONTHLY WEATHER REVIEW, and concluded with the maximum of 1894.1. These epochs are repeated in Table 3 and the table is extended to include the maximum of 1917. In addition, are given the time interval between successive maxima and minima. In order to add the additional years' data to the mean of the sunspot period, these values were averaged and the revised value is 11.2 years, as opposed to the previously published value of 11.12 years.

[4] 1902, 30: 171–176.

[5] Vol. 5, pt. 6, p. 365.

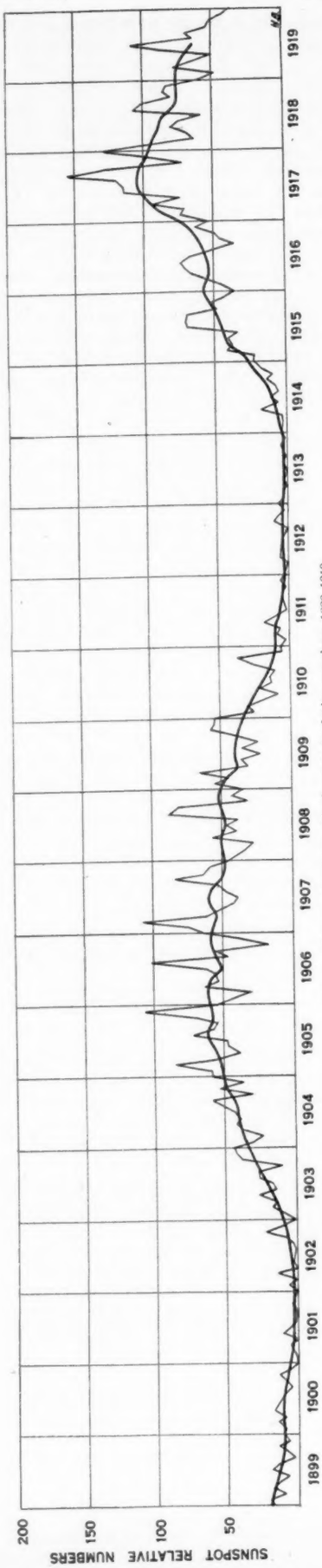

FIG. 1.—Observed and smoothed sunspot relative numbers, 1899–1919.

TABLE 3.—*Epochs of sunspot maxima and minima.*

Minima.			Maxima.		
Epoch.	Weight.	Period.	Epoch.	Weight.	Period.
1610.8	5		1615.5	2	
		8.2			10.5
1619.0	1		1626.0	5	
		15.0			13.5
1634.0	2		1639.5	2	
		11.0			9.5
1645.0	5		1649.0	1	
		10.0			11.0
1655.0	1		1660.0	1	
		11.0			15.0
1666.0	2		1675.0	2	
		13.5			10.0
1679.5	2		1685.0	2	
		10.0			8.0
1689.5	2		1693.0	1	
		8.5			12.5
1698.0	1		1705.5	4	
		14.0			12.7
1712.0	3		1718.2	6	
		11.5			9.3
1723.5	2		1727.5	4	
		10.5			11.2
1734.0	2		1738.7	2	
		11.0			11.6
1745.0	2		1750.3	7	
		10.2			11.2
1755.2	9		1761.5	7	
		11.3			8.2
1766.5	5		1769.7	8	
		9.0			8.7
1775.5	7		1778.4	5	
		9.2			9.7
1784.7	4		1788.1	4	
		13.6			17.1
1798.3	9		1805.2	5	
		12.3			11.2
1810.6	8		1816.4	8	
		12.7			13.5
1823.3	10		1829.9	10	
		10.6			7.3
1833.9	10		1837.2	10	
		9.6			10.9
1843.5	10		1848.1	10	
		12.5			12.0
1856.0	10		1860.1	10	
		11.2			10.5
1867.2	10		1870.6	10	
		11.7			13.3
1878.9	10		1883.9	10	
		10.7			10.2
1889.6	10		1894.1	10	
		12.1			12.3
1901.7	10		1906.4	10	
		11.7			11.2
1913.6	10		1917.6	10	

SMUDGING AS A PROTECTION FROM FROST.

By HERBERT H. KIMBALL and FLOYD D. YOUNG.

[Weather Bureau, Washington, D. C., June 7, 1920.]

There are three quite different types of oil-burning heaters in general use on the Pacific coast. They are commonly designated high-stack, short-stack, and open or lard-pail heaters.[1] The distinguishing characteristic of the high-stack heater is that abundant draft is provided, and almost complete combustion of the oil results, with the formation of only light smoke. On the contrary, the lard-pail type of heater has insufficient draft for complete combustion, and a dense smoke results. The short-stack heater is intermediate to the other two types with respect to both combustion and smoke.

Where the location of orchards or other vegetation to be protected is near a city or town of considerable size the smoke cloud from numerous lard-pail or short-stack heaters may be highly objectionable. On the other hand, it is maintained by some that the smoke cloud is a necessary accompaniment of efficient orchard heating, since it retards not only nocturnal cooling of the ground and lower air strata, but also the escape of the heat produced by combustion from air near the ground, where it is most needed, to higher levels.

Some measurements of the rate at which heat is given off by different types of heaters, and of comparative rates of nocturnal radiation under and outside a smoke cloud produced by heaters, will be of interest in this connection.

Through the kindness of Mr. J. E. Adamson, of Pomona, Calif., a Scheu (high-stack) and a California (low-stack) heater were received at the central office of the Weather Bureau early in 1919. On the evening of January 21 they were set up on the Weather Bureau grounds at a distance of 10 feet from Smithsonian pyranometer No. 2,[2] which had its glass cover removed, and the flat surface containing the blackened strips in a vertical plane squarely facing the heaters.

Before the heaters were fired the pyranometer shutter was opened and the outgoing radiation to the sky and surrounding buildings measured. The loss of heat was found to be at the rate of 0.045 calories per minute per square centimeter. The Scheu heater was then lighted and measurements given in Table 1 were obtained.

TABLE 1.—*Measurements of radiation from a Scheu orchard heater, Jan. 21, 1919.*

[Surface of pyranometer vertical and at level of center of lower section of stack.]

Time.	Radiation from heater. cal. min. cm.²	Remarks.	Time.	Radiation from heater. cal. min. cm.²	Remarks.
p. m.			p. m.		
7:50	0.217	Heater red hot.	8:16	.....	Air temperature 46.2° F.
7:53	.245				
7:54	.249		8:17	.107	Funnel slightly red.
	.234		8:19	.259	Very red.
7:55	.276		8:20	.276	
7:56	.255		8:21	.263	
7:57	.249		8:22	.265	
7:58	.242		8:24	.274	
7:59	.198	Drafts partly closed.	8:25	.286	
8:00	.121	Drafts partly closed; only small section of pipe red.	8:27	.272	
			8:29	.099	Almost no red.
8:10	.124	Lower section of funnel slightly red.			
	.132				

It will be seen that when the stack of the heater had become red-hot the pyranometer appeared to be receiving heat from it at an average rate of 0.250 gram calories per minute per square centimeter of normal surface; when very red the intensity was about 10 per cent greater. With only a slight indication of red the apparent radiation was at the rate of about 0.100 gr. cal.

The above rates must be increased by 0.045 gr. cal., the measured rate of cooling, to obtain the true rate of heating. This gives 0.320, 0.295, and 0.145 calories for the radiation from the heater when the stack is very red, red, and only slightly red, respectively.

Similar measurements made with an Adamson high-stack heater in an orange grove at Pomona, Calif., on February 26, 1920, after adding 0.032 for the measured rate of cooling, give 0.252 calories for the radiation from a red-hot heater and 0.117 calories when the stack had lost its redness.

The following measurements have been obtained on the rate of radiation from short-stack and lard-pail heaters, the pyranometer in each instance being exposed as in the measurements on the high-stack heaters.

[1] See Farmer's Bulletin 1096, pp. 20-21, for illustrations and descriptions of these heaters.

[2] For a description of this instrument, see Smithsonian Misc. Coll. 66, Nos. 7 and 11.

Place.	Date.	Kind of heater.	Rate of cooling.	Measured heating.	Total heating.
			Cal.	*Cal.*	*Cal.*
Washington, D. C.	Jan. 21, 1919	California	0.045	0.055	0.100
Pomona, Calif.	Feb. 26, 1920	do	.032	.072	.104
Medford, Oreg.	Apr. 3, 1920	Lard pail	.027	.053	.080

The high-stack heaters, with their nearly complete combustion of oil, radiate more than twice as much heat as the short-stack heaters and three times as much as lard-pail heaters. It has been noted by Young[3] that they do not show this degree of increased efficiency in raising the air temperature near the ground, perhaps because the high and hot stack facilitates the escape of heated air to higher levels.

At Pomona, Calif., on December 30–31, 1918, and on January 1–2, 1919, Young obtained measurements on the rate of nocturnal radiation in an orange grove throughout nights on which heavy smoke was produced by the use of short-stack heaters, using for this purpose Weather Bureau pyrgeometer No. 2.[4]

Comparison of these with similar measurements obtained on nights when there was was no smoke indicate a decrease in the rate of nocturnal radiation on December 30–31 from 0.110 calories per minute per square centimeter to an average of 0.098 calories, and on January 1–2 from 0.115 to 0.103 calories, or an 11 per cent decrease on December 30–31 and a 10 per cent decrease on January 1–2. The readings under the smoke cloud were irregular, as we would expect, and on both nights showed maximum depressions of 28 per cent.

At Medford, Oreg., on the night of April 17–18, 1920, Young measured the rate of nocturnal radiation in an orchard in which lard-pail heaters were lighted at midnight and in a neighboring orchard in which there was no firing. The results indicate a decrease in the rate of radiation under the smoke cloud from 0.109 calories to an average of 0.099 calories per minute per square centimeter, or a 9 per cent decrease, with a maximum decrease of 26 per cent.

We may summarize our results as follows:

The presence of a dense smoke cloud diminishes nocturnal radiation on an average about 0.011 calories per minute per square centimeter of surface, with maximum effects of nearly 0.030 calories.

At a distance of 10 feet the intensity of radiation from a lard-pail heater is about 0.080 calory per minute per square centimeter; from a short-stack heater, about 0.100 calory; from a high-stack heater when just turning red, 0.120 calory; and when completely red, from 0.250 to 0.300 calory.[5]

Since the intensity of radiation varies inversely as the square of the distance from the source of heat, at a distance of 15 feet from the heaters it will be less than half, and at 20 feet about one-fourth that given above.

The heating by radiation is in addition to the heating by conduction and convection of hot air and gases from the burning oil and its immediate vicinity.

We must therefore conclude that the retardation of nocturnal radiation by the smoke cloud plays an insignificant part in frost protection.

[3] Farmers' Bulletin 1096, p. 20.

[4] For a description of this instrument see the MONTHLY WEATHER REVIEW, February, 1918, pp. 58–61.

[5] The air temperature at the time these results were obtained was about 45° F. All the heaters were nearly full of oil.

EFFECT OF TOPOGRAPHY ON TEMPERATURE DISTRIBUTION IN SOUTHERN CALIFORNIA.

By FLOYD D. YOUNG, Meteorologist.

[Author's Abstract.]

From observations in the Pomona Valley, Calif., it appears that there is little, if any, advantage to be gained by locating an orchard on the upper portion of a long, uniform slope with a fall of 150 feet or less to the mile. However, in even slight depressions of whatever shape or direction, on this slope, the frost hazard is likely to be considerably greater. This also applies to points located directly at the base of the slope, where the ground begins to rise in the opposite direction.

In figure 1 is shown a rough profile of a sloping valley floor, from the foothills on the left, down to and over the summit of an isolated ridge near the lowest part of the

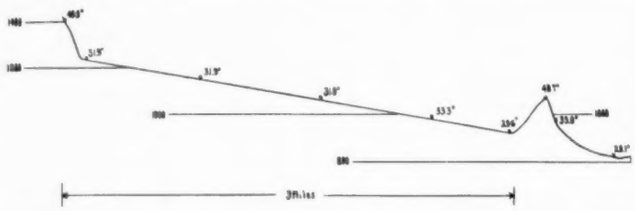

FIG. 1.—Profile of valley, showing average minimum temperatures for 29 clear nights at stations on slopes of varying steepness. Altitudes are in feet above sea level. The gradual slope is not so regular as shown here, but nevertheless there is little variation in the rate of fall.

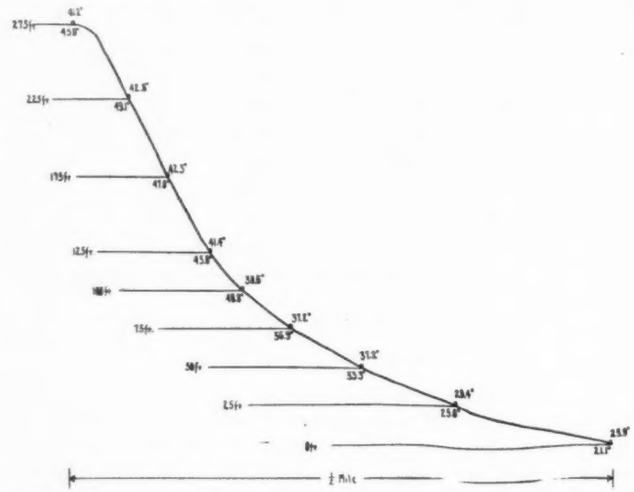

FIG. 2.—Profile of steep slope of ridge shown at the right in figure 1. Elevations are in feet above the base station. Locations of stations shown by small black squares. The average minimum temperature for 45 clear nights during the winter of 1918–19 is shown above each station. Minimum temperatures registered on the night of January 5–6, 1919, are shown below each station.

valley. The figures above each station represent the average minimum temperatures for 29 clear nights during the winter of 1917–18. The contrast between temperature inversions on the steep and the gradual slopes is brought out distinctly.

Temperature inversions on the steep slope shown at the right in figure 1 are shown in figure 2. At the end of the 1918–19 frost season, when these records were obtained, the fruit in an orange grove surrounding the base station was a total loss, while delicate avacado trees in full bloom, located at the 100-foot station, were practically uninjured.

An interesting fact brought out in the observations on this slope is that the highest average minimum temperature was found at the 225-foot station, 50 feet below the summit of the ridge; the minimum temperature at the summit was as high as that at the 225-foot station on only one night during the season. The summit of the ridge is well rounded and the ground sloped away from the summit station in all directions. The steep slope began about 20 feet from the thermometer shelter.

THE PRINCIPLE OF THE CONSERVATION OF ANGULAR MOMENTUM AS APPLIED TO ATMOSPHERIC MOTIONS.

H. W. CLOUGH.

[Weather Bureau, Washington, June 28, 1920.]

The change in the relative easterly velocity of a body moving freely without friction on the earth's surface, due to its variation in latitude, sometimes referred to as the change of velocity with change of latitude, was first imperfectly recognized by Hadley about 1735, who explained the trade winds in this manner. He assumed that a body tends to retain its initial absolute gyratory velocity when forced to another parallel. Ferrel, however, showed that the law of conservation of angular momentum or the preservation of areas applies to a body on the earth's surface, which even at relative rest is gyrating around the earth's axis with a velocity proportional to the cosine of the latitude. Such a body, on being forced to another latitude, tends to preserve its angular momentum, hence must change its absolute east velocity inversely as the cosine of the latitude. A body then moving toward the pole would acquire a relative easterly velocity. The formula for the increase in relative easterly velocity in a body moving from lat. ϕ to lat. ϕ_1 is $V_1 = 465$ m. p. s. $\left(\frac{\cos^2\phi}{\cos\phi_1} - \cos\phi_1\right)$. For example, a body at *rest* in lat. 70° would acquire at lat. 80° a relative easterly velocity of 232.6 m. p. s.

It is well known, however, that the enormous velocities thus called for by the principle of equal areas do not exist in the atmosphere, and since this principle is of rigorous application to all air motions, the problem is to account for the moderate velocities actually observed.

Hadley accounted for the difference between the theoretical and the actual strength of the trade winds by the retarding influence of friction with the earth's surface.

Ferrel [1] arrives at the following theoretical west-east velocities for a frictionless atmosphere on a smooth rotating globe with a decrease in temperature from the equator to the poles. The plus signs are the easterly velocities; the minus signs, westerly velocities.

Latitude	Velocity per hour.	Latitude.	Velocity per hour.
	Miles.		*Miles.*
90°	∞	35° 16′	0
80°	+3807	30°	−100
70°	+1669	20°	−239
60°	+ 865	10°	−320
50°	+ 410	0°	−346
40°	+ 108		

He attempted to show that these excessive velocities, required by the so-called "canal theory," could be reduced to moderate values by introducing proper coefficients of friction. He states ("A Popular Treatise on the Winds," p. 118, par. 81):

> The velocities of the east and west components at the surface, depending upon the forces of momentum, depend very much upon the nature of that surface. For the velocities increase until the resistances to the motions are equal to the forces producing them, so that the smoother the surface and the less the friction between the air and that surface the greater the velocities. If there were no resistance from the earth's surface these velocities would be very great, but on account of the smallness of the forces giving rise to them and maintaining them by overcoming friction when they are once established, these velocities are comparatively very small.

Oberbeck's theory likewise calls for excessive velocities in middle latitudes.

> Friction, furthermore, is to be considered since without it the atmospheric currents under the continuous influence of accelerating forces would attain to indefinitely great velocities. (Abbe's translation, The Mechanics of the Earth's Atmosphere, *Smithsonian Misc. Col.*, Vol. 34, Art. X.

Von Helmholtz' theory of atmospheric circulation introduced resistances due to vortex motions, which he conceived as originating from the mutual interaction of air currents. One of his assumptions is that the internal friction of the atmosphere, in the higher levels at least, is practically negligible.

Bigelow's theory involves horizontal counter currents in the lower levels from the surface to 2 or 3 kilometers, facilitating interchange of polar and equatorial temperatures and tending by the formation of vortices to retard the upper circulation to the moderate velocities actually observed.

The validity of Ferrel's "canal theory" has been questioned by many since it involves a retardation of the upper currents far greater than could conceivably be accounted for by viscosity, surface friction, turbulence, vertical convection or vortex motions.

On the other hand the rapid upper east wind over the equator, or the "Krakatoa wind," by some [2] described as a wind without gradient, has been explained as a result of the transference of air from a position of relative rest at about latitude 14° or 15°, to the equator, the relative westward velocity being increased in accordance with the law of preservation of areas. Evidently in this case no retarding or damping influences are desirable.

Many meteorological textbooks make vague and misleading references to this subject. Hann (Lehrbuch der Meteorologie, 3d ed., p. 433) says:

> According to the principle of the preservation of the moment of rotation, air passing from the equator toward higher latitudes acquires in this way extraordinarily great easterly components. Actually, friction, the mixing of air masses, etc., prevent the attainment of such velocities.

Angot (Traité de Élémentaire Météorologie, p. 154):

> It may be shown that if friction were absent the air, acquiring a great relative easterly velocity, could not, under the effect of the centrifugal force which results from the relative velocity, remain in the vicinity of the pole.

Milham (Meteorology, p. 62):

> The air masses will be deviated to the right in the northern hemisphere and become more and more a west current encircling the pole in a great whirl. As this ring of whirling air about the pole approaches it the mass remains constant, the radius is decreasing and thus the velocity must steadily increase and it has been computed that if the velocities were not held down by friction they would amount to hundreds of thousands of miles per hour.

[1] Values computed by Bigelow from Ferrel's equation. International Cloud Report, p. 603.

[2] Teisserenc de Bort, L. Report on the present state of our knowledge respecting the general circulation of the atmosphere, 1893, p. 5.

Moulton (An Introduction to Astronomy, p. 86):

> If it were not for friction with the earth's surface, a mass of air moving from latitude 40° to latitude 45°, a distance of less than 350 miles, would acquire an eastward velocity with respect to the surface of the earth of over 40 miles per hour.

The impression gained by reading these extracts is that air moving from one latitude to another undergoes thereby a change in its velocity with reference to the earth's surface, while its velocity remains unchanged if it moves along a parallel. The increase in the velocity thus acquired is supposed to be reduced by friction so that only moderate velocities actually result.

Davis (Elementary Meteorology, p. 103) correctly pointed out the effect of a change in latitude on air masses. He says, referring to the trade winds:

> The explanation still generally current follows that given by Hadley, in brief, as follows: If a mass of air moves from latitude 30° north toward the Equator, it advances upon latitudes whose eastward rotary velocity is greater and greater, and in consequence of this the air lags behind and, hence, appears as an oblique northeast surface wind. Indeed, if it were not for the friction with the surface of the land and sea, by which the advancing air continually acquires something of the eastward motion of the latitude that it enters, there should be a violent westward hurricane of a hundred miles or more at the Equator according to this theory.
>
> This explanation contains two serious errors, which are here referred to because they have gained general currency. Hadley's explanation implies that there is no effect produced on motion to the east or west, while, as stated above, the deflective force arising from the earth's rotation is independent of the direction of motion. Again, Hadley's explanation teaches that a body moving toward the Equator continually lags westward, so that if friction had no effect it would attain a great velocity to the west when it reached the Equator. This is wrong. The lagging, if such an expression is introduced at all, can not be continually in one direction, as to the west, but can only be at *right angles to the momentary direction of motion*, and hence can produce *no effect on the velocity*. If a body were given a velocity of 25 miles an hour to the south when in latitude 30° north, and was supposed to move without friction over a level surface, it would continue to move at the same moderate rate whatever latitude it reached; while Hadley's explanation would give it a velocity of a hundred miles or more westward at the Equator. A proper understanding of the true value and action of the deflective force should therefore be introduced into the popular teaching of meteorology.

Notwithstanding the fact that Davis wrote this in 1893, many later writers have continued to give the same erroneous explanation of the movement of air masses in obeying the law of preservation of areas. This may be partly accounted for by a failure in Davis's criticism to discriminate clearly between relative velocity and easterly velocity.

In view of the divergence among theoretical meteorologists regarding this problem, it is not surprising that popular writers and nonmathematical students experience difficulty in correctly understanding the principles involved.

The problem is simplified by a preliminary consideration of the motion of a body moving without friction on the globe, under the deflecting force of the earth's rotation. The motion of an air particle is but little more complicated. The theory is simple but leads to rather complex mathematical formulæ for expressing the movement under varying conditions of velocity and latitude.

F. J. W. Whipple has given the most complete discussion of the paths of bodies moving without friction on a rotating globe. (Phil. Mag., vol. 33, p. 457.)

Take the simple case that the body moves in such a small range of latitude that the sine of the latitude which enters into the formula expressing the deflecting force may be regarded as constant. This formula is, for a unit mass of 1 gram, $2v\omega \sin \phi$, where v is the velocity of the body in centimeters per second, ω the angular velocity of the earth's rotation per second, and ϕ the latitude. Since this force always acts at right angles to the momentary direction of motion of the body, the latter preserves its initial relative velocity, or its velocity with reference to the earth's surface, under all circumstances. If the sine of the latitude is constant, or nearly so, the deflective force is constant and the body being continually deflected from its course by equal angles in equal times describes a circle. Actually the circle is not quite closed and the path forms a series of overlapping loops along which the body gradually moves westward along a parallel. The path being circular, there must be equality between the deflecting force and the centrifugal force due to the inertia of the body. The latter force is proportional to $\frac{v^2}{r}$, v being the initial velocity and r the radius of curvature of its circular path. The deflecting force is $2\omega v \sin \phi$. Hence $r = \frac{v}{2\omega \sin \phi}$ or $\frac{6857v}{\sin \phi}$. The formula gives the radius of curvature in meters, if the velocity is expressed in meters per second. The table in Davis's Meteorology (p. 104) gives incorrect values of the radius of curvature corresponding to varying latitudes and velocities. The values should be divided by two to obtain correct value of r.

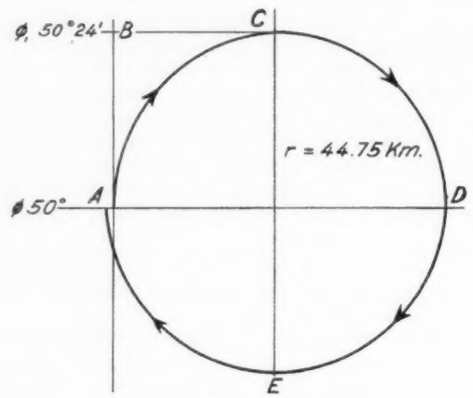

FIG. 1.

Figure 1 illustrates the approximately circular path of a body projected due north from a point A at latitude ϕ. It describes a circular path with a radius r reaching its extreme northern limit at C in latitude ϕ_1, where its motion is due easterly. Continuing to be deflected, it crosses latitude ϕ at D, moving due south and returns nearly to its starting point, crossing latitude ϕ slightly west of A.

Assume a body projected northward from a point on the fiftieth parallel with a velocity of 5 meters per second. Substituting in the formula above, r equals 44.75 kilometers. The latitude ϕ_1 reached at the most northerly point of its path where its motion is due easterly is 50° $\frac{4475}{11118}$, or 50° 24′ N., 111.18 kilometers being the length of a degree of latitude along the meridian at latitude 50°. The time of revolution is 15.7 hours. The cosine of 50° is 0.6428 and of 50° 24′ is 0.6374. Substituting in the above formula for change in easterly velocity, $v_1 = 465\left(\frac{0.6428^2}{0.6374} - 0.6374\right) = 5$ meters per second. In this formula v_1 represents the change in easterly velocity in accordance with the law of areas, experienced by a body

moving from latitude ϕ to latitude ϕ_1. Easterly velocity signifies the easterly component of the relative velocity of the body. The relative velocity is the initial velocity of projection, irrespective of direction. If the body is projected due north, its easterly velocity is zero at the point of projection which is A in the figure. As it curves to the eastward the easterly component of the relative velocity gradually increases until when it reaches C its easterly velocity equals its relative velocity. In the above illustration, the body moving from latitude 50° to 50° 24′ acquires an easterly velocity in accordance with the law of preservation of areas of 5 meters per second in excess of that which it possessed at latitude 50°. The easterly velocity at A was zero. Hence at latitude 50° 24′ it has acquired an increased easterly velocity of 5 meters per second but its relative velocity is unchanged. Continuing to move southward, it loses its easterly velocity at D and gains a westerly velocity of 5 meters per second at E, the most southerly point reached.

Therefore a body moving freely under the influence of the earth's deflective force undergoes variations in its easterly velocity in strict accordance with the principle of the preservation of areas. Its relative velocity or initial velocity of projection remains unchanged. The deflective force acts perpendicularly to the momentary direction of motion, causing the body to describe a nearly circular path with unchanged initial relative velocity. A body moving freely over the earth's surface from one latitude to another can and does obey the law of equal areas without any change in its relative velocity. At the extreme latitude which it is able to reach in its curved path it gains or loses by the law of areas an easterly velocity precisely equivalent to its initial velocity, if the direction of projection is along a meridian.

In the above quotation from Davis the term velocity is used in one sense only, meaning relative velocity. Referring to Hadley's teaching that a body moving toward the Equator continually lags westward and would attain a great velocity to the west when it reached the Equator, he makes the criticism that this lagging can produce no effect on the velocity, meaning relative velocity. Hadley was correct in the sense that a change of latitude involves a change in the easterly velocity of a freely moving body, but he was wrong in assuming that a change in relative velocity would result. In Davis's illustration a body given a velocity of 25 miles per hour to the southward at latitude 30° would not even reach latitude 28°, a fact which he omitted to state. In order that it may reach the equator it should have an initial southward velocity of 116 meters per second, and at the Equator it would be moving due westward with its initial velocity.

Thus moving air does not acquire the excessive velocities implied in the extracts given above, because it does not move over the required range of latitude. The increase in easterly velocity is checked when the limiting latitude is reached, hence friction is obviously not needed to reduce the excessive velocities.

In order that the body may continue in its original direction of projection, a force equal and opposite to the deflective force must act on the body. Assume that the body moves on a plane with an inclination to the left of the direction of projection. With the direction due north, the plane will slope to the west. If the inclination of the plane is such that the small component of gravity tending to draw the body down the plane is equal to the deflective force, the inclination of the plane gradually increasing with increasing latitude, the body will continue moving in a due north direction with uniform velocity.

The uniform motion of a body on an inclined plane is strictly analogous to that of air particles along straight isobars, neglecting friction. Consider isobars extending north and south with low pressure to westward and high pressure to eastward. The air particles will have a movement from south to north with uniform velocity under the equal and opposite influences of the gradient tending to force the particles to the westward and the earth's deflective force tending to swerve them eastward. It is obvious that allowing for an increase in gradient with increasing latitude, the condition of steady motion is realized and the air particles move over a wide range of latitude with uniform velocity. The principle of the preservation of areas is not thereby invalidated nor is it necessary to assume that retarding or damping influences operate to reduce the increased velocities called for by the change of latitude. The increase of relative easterly velocity due to increase of latitude is exactly neutralized by the increase of westerly velocity due to the gradient.

NOTES, ABSTRACTS, AND REVIEWS.

METEOROLOGICAL INFLUENCES OF THE SUN AND THE ATLANTIC.[1]

By Prof. J. W. GREGORY, F. R. S.

[Reprinted from *Nature* (London), Aug. 5, 1920, pp. 715–716.]

The prospects of long-period weather forecasting and the explanation of major variations of climate appear to rest on two lines of investigation. The effort of the first is to connect changes in the weather with those in oceanic circulation; the second attributes the changes to variations in the heat supply of the sun acting through the atmospheric circulation. Each theory has its own *a priori* probability. The oceanic control of climate has the attraction that each ocean is a potential refrigerator, since it is a reservoir of almost ice-cold water, which, if raised to the surface, must chill the air, disturb the winds, and enable polar ice to drift further into the temperate seas. Hence Meinardus, for example, connected the range of ice in the Icelandic seas and harvests in Germany with variations in the surface waters of the North Atlantic. The alternative theory has the recommendation that, since the earth receives its heat supply from the sun, variation in solar activity is the natural cause of climatic change.

The oceanic theory must be true in part. The abnormal character of some coastal climates is clearly due to the upwelling of cold water under the influence of offshore winds. Moreover, unusual spells of weather on some of the coasts and islands of the Atlantic follow changes in the quality of its surface water, as proved by Dr. H. N. Dickson for Northwestern Europe, and by Prof H. H. Hildebrandsson's demonstration that for 15 years there has been constant coincidence between rainfall in British Columbia and the weather in the following autumn in the Azores. The alternative theory that the

[1] Björn Helland-Hansen and Fridtjof Nansen, "Temperature Variations in the North Atlantic Ocean and in the Atmosphere." Introductory Studies on the Cause of Climatological Variations. Smithsonian Miscellaneous Collections, vol. lxx., Publication 2537. 1920. Pp. viii+408+48 plates.
Author's abstract of original work in German, published in MONTHLY WEATHER REVIEW, April, 1918, **46**: 177–178.

main factor in controlling the temperature of the earth is the varying heat from the sun acting through changes of wind and atmospheric pressure has been mainly advanced by the work of Sir Norman and Dr. W. J. S. Lockyer and of Prof. Frank Bigelow; they are now strongly reinforced by Dr. B. Helland-Hansen, the director of the biological station at Bergen, and Dr. Nansen, who remark that these views have hitherto received but little support.

The important memoir by these Norwegian oceanographers is based on a detailed study of variations in the temperatures of the air and surface waters along the steamer route from the English Channel to New York. Their detailed discussion of the results and associated problems is accompanied by a valuable series of temperature charts of the North Atlantic for the months of February and March from 1898 to 1910. The data are often uncertain, and the inconvenience of the centigrade thermometer with its zero at freezing point is illustrated by records of water temperature of $-3°$ C. and $-4°$ C., which have to be rejected. Drs. Helland-Hansen and Nansen, after discussion of the theory of oceanic control, reject it as quite inadequate. Thus the chilling effect of the drift of ice into the North Atlantic they estimate as "vanishingly small" in comparison with the heat transported by the air, or even by ocean currents. They consider that, though not yet fully established, the variations of the air temperature preceded, and were therefore not the result of, those of the water temperature. They hold that the variations of temperature require some much greater and more general cause than oceanic variations.

Faith in the meteorological influence of oceanic circulation was greatly favored by the exaggerated estimates attached to what the authors refer to as "the so-called Gulf Stream." Thus the warmth of the water off the Norwegian coast was attributed to that current even by Pettersson and Meinardus; this conclusion the authors describe as surprising because the evidence of salinity shows that the Norwegian waters are coastal and quite different from those of the mid-Atlantic. This sound criticism of the Swedish and Münster oceanographers renders it the more remarkable that there is no reference, either in the long historical discussion or in the bibliography, to the pioneer work on this subject in the earlier papers by Dr. H. N. Dickson, or to his observations as to the seasonal entrance of the Atlantic water into the North Sea. The authors agree with Schott in terminating the Gulf Stream west of Newfoundland, and calling the current off Western Europe the "Atlantic current," for which Dickson's name of "European current" is more descriptive and definite. The Atlantic is a large mass, and has a whole system of currents, of which the so-called Atlantic current is by no means the largest.

Drs. Helland-Hansen and Nansen, after rejecting the oceanic theory, accept as firmly established the dependence of variations in the earth's temperatures on the solar variations proved by sun spots, the numbers of solar prominences, and terrestrial magnetic disturbances. They point out that the influence of the sun on the weather of any area on the earth depends upon so complex a series of factors that the results at first sight appear inconsistent. The crude expectation that an increase of heat supply from the sun would raise the temperature of the whole earth was early dismissed, for the greater evaporation would lower the temperature on the coast lands by increased clouds, rain, and snow. Blanford pointed out, for example, the see-saw of oceanic and continental conditions; but, though his view has not been fully confirmed, his principle is supported by the proof that regions are oppositely affected by changes in the heat supply from the sun. Bigelow has divided the world into three groups of regions: In the "direct" group the temperature conditions vary directly with the sun; in the "indirect" group the variations agree in time, but are opposite in character; in the third, the "indifferent" group, there is no regular correspondence. Sir Norman and Dr. W. J. S. Lockyer have shown that a region may for years belong to the "direct" group, then suddenly become "indirect," and later return to the "direct" group. Drs. Helland-Hansen and Nansen accept this frequent inversion, and also their explanation of the phenomenon.

The author's instructive study of North Atlantic temperatures therefore strengthens the case for solar variations acting through the atmospheric circulation as the main cause of meteorological changes. To what extent the ocean helps by regulating the air temperature and circulation the authors do not discuss in the present memoir; that and other questions are to be dealt with after further investigations in a series of memoirs to which the present is introductory. The usefulness of the promised memoirs would be increased (should they have as many appendices and supplementary notes as the present) if each were provided with an index.

SERVICES OF A VESSEL-REPORTING STATION OF THE WEATHER BUREAU.

The following account of the grounding of the Dutch S. S. *Arakan* on August 29, 1920, near Point Reyes Light, Calif., has been furnished by Mr. J. C. Smith, in charge of the vessel-reporting station of the Weather Bureau at that place. It is published as an illustration of the services being rendered by the Bureau at vessel-reporting stations. The *Arakan* was subsequently refloated and arrived at San Francisco on September 1. The damage sustained, if any, is not known. The officers of the *Arakan* have for many years cooperated with the Bureau in marine work, and the news of her misfortune was received with regret.

On August 29, 1920, at 2 p. m. the Dutch S. S. *Arakan*, 5,000 gross tons, with cargo of sugar and rubber, bound from Batavia for San Francisco, went aground about 6 miles north of this station, during a dense fog. S. O. S. calls resulted in tugs being dispatched from San Francisco. However, they have not succeeded in pulling the vessel off. The vessel's wireless outfit failed on the 30th, and as a result this office was called upon for considerable information by maritime interests and newspapers of San Francisco. Weather and sea conditions were inquired about frequently; also, topographic conditions in the vicinity of the vessel. An aeroplane was dispatched from San Francisco to the scene of the wreck on the strength of information given by this office. Unless the vessel is pulled off the sand within a short time it may break amidship, resulting in the loss of the vessel as well as the valuable cargo.

This office remained open day and night during the critical stage answering inquiries by long-distance telephone.—*F. G. T.*

FIRST SCIENTIFIC CONFERENCE, PAN-PACIFIC UNION.

Under the auspices of the Pan-Pacific Union a scientific conference for the purpose of outlining a plan of exploring the Pacific Ocean was held at Honolulu, Hawaii, beginning August 2, and ending August 20, 1920. This conference brought together a few more than 100 scientists from the countries bordering on the Pacific Ocean. The United States, Australia, New Zealand, Japan, and the Philippine Islands were well represented.

China, Canada, Samoa, and Tahiti each had one delegate. There were none to represent Mexico, Central or South America.

Dr. Herbert E. Gregory was elected chairman of the conference, and Dr. Arthur L. Dean was elected vice chairman and secretary. Sections were organized as follows: Anthropology, Clark Wissler, leader; biology, Charles Chilton, leader; botany, W. E. Safford, leader; entomology, F. Muir, leader; geography, William Bowie, leader; geology, T. Wayland Vaughan, leader; and seismology and volcanology, Fusakichi Omori, leader.

On week days all the members of the conference met during the forenoons in the throne room of the Capitol Building of Hawaii from 9 a. m. till noon. At these meetings papers of general interest were read and discussed.

During the afternoons the different sections held their meetings in small halls. They generally began at 2 p. m. and were concluded at about 5 p. m. Only topics of especial interest to each particular branch of science were discussed at these meetings. This program was adhered to, except when broken by an excursion to the island of Hawaii for the purpose of visiting the volcano of Kilauea. The trip to the volcano occupied five days and it was of especial interest to volcanologists, as talks on volcanism were given and discussed by them.

Delegates representing no less than 24 branches of science were present at the conference. There were 15 botanists, 14 entomologists, 12 zoologists, 11 geologists, and an equal number of ethnologists. Meteorology was represented by only two delegates, who were assigned to the department of geography under the leadership of William Bowie. The oceanographers were also assigned to this department, and they, together with those interested in geodesy, hydrography, and terrestrial magnetism, took part in the discussion of the papers on meteorology.

When meteorology was brought before the general meeting on August 18—preliminary to the passing of resolutions to be presented by the department of geography—some of the Australian delegates brought out the fact that the meteorological station on Macquarie Island had been of great help in improving the Australian weather forecasts. This station was closed during the war and has not yet been reopened.

On August 20 a large number of resolutions was passed by the members of the conference,[1] and among them were the following on meteorology:

RESOLUTIONS ON METEOROLOGY.

Investigations in meteorology, or the physics of the atmosphere, designed to lead to an accurate, scientific knowledge of atmospheric phenomena are of recognized importance. Very little is known of the behavior of the upper air over the land, and still less over the ocean. The fundamental aspects of these phenomena are exhibited in their simplest manner over the greatest of oceans, the Pacific. Hence it is necessary to make meteorological observations over the Pacific for use in studying the more complex problems over the land.

Moreover, the collection and prompt dissemination of marine meteorological data are of great benefit to humanity in carrying on its commerce, and in weather forecasting, which is now limited by a lack of synchronized, uniform, meteorological data over great ocean areas not within the customary track of vessels.

Observations at the place of origin of typhoons, hurricanes, larger cyclonic, and anticyclonic areas, as well as the development, dissipation, oscillation, and translation of the same, are essential to successful forecasting and the study of ocean meteorology. Moreover, the meteorological survey of these ocean areas has practical value; therefore the Governments of the countries bordering on the Pacific Ocean are urged to carefully consider these matters with a view to increasing the number of meteorological vessels and land stations within the confines of this ocean, and on its borders, especially the establishment of vessel-reporting stations in somewhat fixed positions. In considering these matters it is believed that especial attention should be given to increasing the number of stations in the well-known "centers of action."

The Pan-Pacific Scientific Conference commends the ocean navigation companies and their masters of vessels for the valuable assistance they have rendered the meteorological services of the various nations, and urges them to further cooperate, especially in the matter of transmitting their weather reports by radiograph as well as by mail.

Meteorological station on Macquarie Island.—Since the observations made at the meteorological station on Macquarie Island resulted in improvements in the accuracy of weather forecasting, this conference expresses the hope that observations at that station, interrupted by the war, may be resumed at an early date.

Meteorological station on Mauna Loa.—In view of the fact that Mauna Loa, island of Hawaii, the highest accessible point in the central Pacific, offers exceptional opportunities for the exploration of the upper air, it is recommended that a station of the first order be established on its summit for continuous meteorological observations.

The proceedings of the conference will be published by the Pan-Pacific Union at as early a date as possible. There will be included in the publications a tentative plan of operation, which will endeavor to combine the different projects so as to prevent overlapping. Also rules will be supplied so that future operations can be carried on after a uniform plan, in order that work done by one nation will be comparable with that done by other nations.

The citizens of Honolulu were lavish in their hospitality, and the conference closed according to schedule, with regrets on the part of everyone because of the parting of congenial spirits so soon to take place. No time or place was set for another conference, but invitations were extended by both the Australian and New Zealand delegates to hold the next meeting in their countries, and the Honolulu people were equally as anxious to have the next meeting in the Hawaiian Islands.

No one seems to know what the conference will bring forth, though all hope much good will come from it. The problem is certainly one of merit, and its gigantic proportions are such as to make it of international character. It can be solved only through the heartiest cooperation on the part of all the nations bordering on the Pacific Ocean.—*E. A. Beals.*

[1] See *Science* Sept. 24, 1920, pp. 286-287, for the general resolutions, and later issues for those on specific subjects.

ATLAS OF TYPHOON TRACKS.

There has recently been issued from the Zi-ka-wei Observatory, by the director, Louis Froc, S. J., a valuable work on typhoon tracks.[1] It appears in the form of an atlas, containing 21 major and 12 minor charts, with a brief introductory and explanatory discussion. The author states that his first purpose was to issue the charts as an appendix to a more general and detailed study on the oceanic storms of the Far East, but that the publication of such an essay ran the risk of considerable delay, and it was decided to publish the charts at once for the benefit of those interested.

The compilation for the atlas covers a period of 26 years, 1893–1918, during which time a total of 620 storms occurred manifesting typhoon characteristics at some period of their existence. Of the 21 principal charts there is one each for January, February, March, April, May, June, and December, which are the less active typhoon months; three each for July, August, September, and October, when the typhoon season is at its height, and two for November, when activity is decreasing. On the 12 lesser charts the data are summarized in condensed form.

In the introduction the author discusses the following subjects: The meaning of "typhoon," disturbed areas, how to read the charts, the classification of typhoons, and rate of progression on the tracks. Three tables are included—mean speed, extreme speed, and points of recurving on the tracks. There is also an explanatory note accompanying each of the major charts.

The author pays a graceful tribute to those who aided him in the preparation of the "Atlas," as follows:

> We beg to present this work to all those who, by their kind and constant cooperation, for many years now, have made possible and easy the study of so numerous storms, and chiefly to the sailors, who very often in the midst of hard struggle with the elements, have found time to collect observations for the sake of those who would run the same risks after them. To establish each track of the maps there have been made use of at least 10, sometimes 20 or more, reports received from stations on land and ships at sea: and we are glad to show our benevolent cooperators, while offering them our hearty thanks, that the task spontaneously undertaken by them has not been without reaching a very important and useful aim.

The charts for January and February are reproduced in the present issue of the REVIEW. See Charts XI and XII.

The revival of shipping since the war, taking many new vessels into the typhoon area, makes the appearance of this work most timely.—*F. G. T.*

[1] Atlas of the Tracks of 620 Typhoons, 1893–1918, by Louis Froc, S. J., director Zi-ka-wei Observatory, Zi-ka-wei—Chang-hai, 1920.

Charles W. Hendel.

Mr. Charles W. Hendel, of La Porte, Plumas County, Calif., for the past 26 years mountain snowfall observer for the Weather Bureau, was found dead in his bed recently. Though his exact age was not known, he was more than 100 years of age at the time of his death.

Mr. Hendel was born near Dresden, Germany, and received his technical education in that country. He migrated to California during the gold rush "in the days of '49," and for the past 67 years has made his home in La Porte, in the Sierra Nevada Mountains, overlooking the scenic Feather River region. He had the C. E. and M. E. degrees, and practiced the profession of civil and mining engineer for over a half century.

Mr. Hendel's vigor and good health remained with him until the very end. La Porte is many miles distant from the nearest railroad station, and in a region of extremely heavy snowfall. Mr. Hendel was as agile on snowshoes as many a man 50 years his junior. His last weather report, that for August, 1920, was received on time at the San Francisco office of the Bureau. He was a careful and conscientious observer, of the type so eagerly sought as special meteorological observers.—*A. H. Palmer, Weather Bureau Office, San Francisco, Calif.*

COLOR OF THE NIGHT SKY.

By LORD RAYLEIGH.

[Excerpt from *Nature* (London), Sept. 2, 1920, p. 8.]

Eye observations on the relative brightness of a yellow and a blue gelatine film afford "definite evidence that the night sky is yellower or less blue than the day sky.

"This conclusion has been confirmed photographically. A yellow and a dense blue filter were selected, and an Ilford panchromatic plate was exposed to the sky under these. It was seen at a glance that the density under the blue filter was the greater for the twilight sky, while for the night sky this relation was reversed.

"The results point to the conclusion that the light of the night sky, whatever the cause of it may be, is not due to the scattering of sunlight by rarefied gas situated beyond the earth's shadow. The comparative absence of polarization, formerly found, points to the same conclusion."

HOT WINDS AND "NORTHERS" AT TAMPICO, MEXICO

The Tampico Tribune of April 10 and 24, 1920, contains notes by Mr. S. A. Grogan, the meteorological observer for the Mexican Gulf Oil Co. on the "norther" of April 3, 1920, and the hot winds of April 16–18. The first three months of the year had brought to Tampico 12 "northers," but the one of April 3 was decidedly the most severe. The wind, which came suddenly, attained a force of 60 miles per hour, and for two hours averaged 50 miles per hour. This wind was accompanied by a marked rise in the barometer of 0.64 inch in 37 hours. Mr. Grogan has previously discussed these northers.[1]

The hot southwest winds have also been discussed.[2] These are apparently caused by dynamic heating as the dry winds descend from the Mexican plateau. The maximum temperatures on the three days were successively 98.8° F., 103.5° F., and 106.4° F. The relative humidity at times of observation was 20 per cent, 15 per cent, and 12 per cent, respectively, which was sufficient to warp and split woodwork and furniture.—*C. L. M.*

VARIABILITY OF TEMPERATURE AND DEPARTURE FROM THE MONTHLY MEAN.

By H. FICKER-GRAZ.

[Abstracted from *Meteorologische Zeitschrift*, Jan.-Feb., 1920, vol. 37, pp. 42-43.]

The day to day variability of temperature undergoes from year to year such large variations that a considerable number of years' record is necessary in order to

[1] "Northers" on the coast of Mexico, their effects, and forecast by local observations. Mo. WEATHER REV., July, 1919, 47:469–471.

[2] Hot winds at Tampico, Mexico, Apr. 6–7, 1919. Mo. WEATHER REV., April, 1919, 47:234.

obtain reliable means for each month. The relations, if any exist, between the daily variability of temperature and the mean monthly temperature have not been very thoroughly investigated. For instance, it is possible that in extremely cold months the variability of temperature is greater, and in warm months less, than the average.

Using data compiled by Wahlén from long records of Russian stations, the author has undertaken this investigation. The Russian stations used are Warsaw (101 years), Port Baltic (44 years), Archangel (68 years), Astrakhan (44 years), Katharinenburg (52 years), Barnaul (45 years), and Yakutsk (37 years). In addition, data for Vienna (75 years) and for Pola (40 years) compiled by von Hann, were used.

The results of the investigation were three fold: For Pola, which typifies the climate influenced by the ocean, there was no relation between the variability and the departure from the monthly mean. Vienna, Warsaw, Port Baltic, Archangel, and Astrakhan fall into a second group, in which the following relation seems to hold: In the months colder than normal the variability of daily temperatures is greater than the average; in months warmer than normal, it is less than the average. This region seems to form a transition between oceanic and continental climates. At Barnaul and Katharinenburg in west Siberia, this rule does not hold, and at Yakutsk in east Siberia the relation is reversed; i. e., in winter months colder than normal there is a small variability of temperature, and in those warmer than normal the variability is large.

The proof that these relations are not accidental is to be found in the smooth progression of values from Pola to Yakutsk. The relation is weakest in regions of most intense cold. Great variability of temperature implies cold and warm waves following one another rapidly. But in Yakutsk the lower the monthly mean lies the more uniform the temperature, because of fewer warm waves.[1]—*C. L. M.*

THE LAWS OF APPROACH TO THE GEOSTROPHIC WIND.

By F. J. W. WHIPPLE.

[Abstracted from *Quar. Jour. Roy. Met'l Soc.*, 46, 39–53, Jan., 1920.[2]]

In the steady state, the forces at each level in the atmosphere due to rotation, gradient, and internal friction (eddy viscosity) must balance; in the layer next the surface, the additional drag due to friction is practically equal and opposite to the drag due to the eddies, since it may be shown that the combined effect of pressure and rotation is only one-thirtieth that of one of the other two forces, and hence may be ignored. The actual wind at any level is considered as the vector sum of the gradient wind and a fictitious "relative wind." In the case of straight, parallel, motionless isobars, with uniform distribution of density, gradient, and eddy motion throughout the height considered, the above conditions lead to three laws: I. The relative wind falls off with increase of height according to the exponential law $R = R_0 e^{-(Bz - z_0)}$, where R is the relative wind at the height z, and R_0 that at height z_0; B is a constant, $B^2 = \omega \sin \lambda \, (\rho/\mu)$. II. The direction of the relative wind turns uniformly with increase of height, the circular measure of its azimuth being given by $\phi - \phi_0 = B\,(z - z_0)$. III. The angle between the actual wind near the surface and the relative wind there is 135°. The velocity curve traced out by the lines, drawn from a fixed origin, representing the relative winds at all heights, is the equiangular spiral of Ekman, the constant angle between the radius vector and the tangent (the latter representing transfer of momentum by the eddies) being 45°. The Law of Dynamic Similarity then leads to Taylor's relation, $V_0 = G\,(\cos \alpha - \sin \alpha)$.

The first two laws also hold when G changes with height: $G = G_0 + Az$; then $e^{-3i\pi/4}\, R_0 = a(V_0 - U)$, where $U = A/aB\sqrt{2}$, and $a = K\rho V_0/\mu B\sqrt{2}$, a generalization of Law III. With V_0, and U known, G_0 may be computed; and with the law of change of G with height known, V at any level may be computed. The theory is applied to the case where observation shows east winds at the surface to be replaced by west winds at 2,000 meters, so that the change of gradient wind with increasing height is equivalent to the addition of a westerly component; then for surface winds of equal strength, it is found that the backing of the surface wind is least for south winds, greatest for north winds; the ratio of surface wind to gradient wind is least for southeast gradient wind and greatest for northwest. This shows the tendency for the surface wind to be governed by the geostrophic wind aloft rather than the geostrophic wind at the surface.

The theory is applied in detail to Dobson's Salisbury Plain observations, and again the fact is theoretically confirmed that the gradient speed is attained at about 300 meters, while the gradient direction is not attained until a much greater height. Comparisons of theory with observation are rendered difficult because of the influence of the anemometer exposures, but such comparisons as have been made, especially with the data of T. Koraen, tend to confirm the theory—south winds being much lighter in comparison with gradient winds than those from northwest.

Cf. MONTHLY WEATHER REVIEW: July, 1915, **43**: 315–316; Sept., 1917, **45**: 455; Jan., 1918, **46**: 22; May, 1918, **46**: 211; Oct., 1919, **47**: 703–707.—*E. W. W.*

TECTONIC EARTHQUAKES AND VARIATIONS OF LATITUDE.

By G. ZEIL.

[Abstracted from *Comptes Rendus*, Paris Academy of Sciences, t. 171, pp. 311-313, Aug. 2, 1920.]

Omori, Milne, and Cancani found that destructive earthquakes took place at or near times of maximum or minimum variation of latitude. Brillouin concluded that variations of latitude were caused by sudden internal movements, of seismic origin; Montessus de Ballore's former doubts about this would not now hold, since he has come to believe that earthquakes and epeirogenic movements are one and the same. (*C. R.*, 158, 1833, 1914.)

The present author states that on a parallel of latitude, the various molecules of the lithosphere are in equilibrium two by two, at the opposite extremities of diameters of the circle; if one of these molecules is displaced along the diameter, a seesaw movement of the diameter will take place such that the displaced extremity will be above the normal level of rotation if it approaches the center, and below if it recedes from the center. On the basis of his former studies (see MONTHLY WEATHER REVIEW, 48, 356, June, 1920), Zeil then

[1] The colder the air, the stronger the disturbance necessary to blow it away. But in the coldest weather in continental interiors, such as central Siberia, the winds are usually weak. The warm winds of winter may glide over the cold surface layers for many hours and may not reach the surface at all before they cease to blow.—EDITOR.

[2] Cf. *Science Abstracts*, Apr. 30, 1920, p. 518.

contends that in this manner *centrifugal* earthquakes will cause the polar axis to incline toward the readjusted arch and increase the latitude of the disturbed area; while *centripetal* quakes will cause the opposite. *Antagonistic* quakes will have little or no effect. It has been shown that the Japanese quakes are of two types—those of submarine origin, essentially centripetal, and those of continental origin, essentially centrifugal—and their different methods of action explain why the quakes occur either at maximum or minimum variation of latitude.—*E. W. W.*

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Recherches sur le gradient du potential électrique de l'atmosphère a Upsala. Stockholm. 1917. 57 p. 30 cm. (Kungl. Svenska vetenskapsakademiens handlingar. Bd. 58. N:r 4.)

Pick, W. H.
Notes on ground day visibility at Cranwell, Lincolnshire, during the period Feb. 1 to Apr. 8 (inclusive), 1920. London. 1920. 9 p. 24 cm. (Great Britain. Meteorological office. Professional notes no. 11.)

Rouch, Jules.
Préparation météorologique des voyages aériens. Paris. 1920. 57 p. 24 cm.

Rudge, W. A. Douglas.
Daily range of the atmospheric potential gradient at Bloemfontein, and the influence of dust storms. Cape Town. 1914. p. 75–87. 25½ cm. [Excerpted from Transactions of the Royal society of South Africa. vol. 4, pt. 1.]

Shaw, Sir Napier.
Report on high angle practice, to determine the wind at various heights for comparison with simultaneous determinations by pilot balloon ascents: carried out at firing ground of H. M. S. "Excellent," 25th and 26th of April, 1917. London. 1919. 4 p. 1 folded chart. 24 cm. (Great Britain. Advisory committee for aeronautics. Reports and memoranda, no. 499. May, 1917.)

Strakosch-Grassmann, Gustav.
Ernteaussichten von 1919 bis 1923 und die Bedeutung klimatischer Perioden für Geschichte und Landwirtschaft. Wien. 1919. 466 p. 22 cm.

Sutton, J. R.
Barometric variability at Kimberly and elsewhere. Cape Town. 1914. p. 105–121. 25½ cm. [Excerpted from Transactions of the Royal society of South Africa. vol. 4, pt. 2.]

Taylor, Griffith.
Australian meteorology. A text-book including sections on aviation and climatology. Oxford. 1920. 312 p. 22 cm.

Taylor, G[eoffrey] I[ngram].
Phenomena connected with turbulence in the lower atmosphere. London. [n. d.] 13 p. 24 cm. (Great Britain. Advisory committee for aeronautics. Reports and memoranda, no. 304. Dec., 1916.)

Turpin, H. W.
Carbon dioxide of the soil air. Ithaca, N. Y. 1920. p. 319–362. (Cornell University. Agricultural exper. station memoir 32.)

Zierl, Hermann.
Beiträge zum photochemischen Klima der Zugspitze. Munich. 1919. 19 p. 33 cm. (Sonderabdruck aus dem Deutschen meteorologischen Jahrbuch für Bayern 1919.)

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. F. TALMAN, Professor in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

Annalen der Hydrographie und maritimen Meteorologie. Berlin. 48. Jahrgang. Heft 7. 1920.

Ryd, V. H. Die Reibung in der Atmosphäre. p. 286–293.

Annalen der Physik. Leipzig. Band 62. no. 11. 1920.

Gockel, A. Beiträge zur Kenntnis von Farbe und Polarisation des Himmelslichtes. 1. Die Polarisation in Farben. p. 283–292.

Annales de géographie. Paris. v. 29. 15 juil., 1920.

Camena d'Almeida, P. Les saisons dans le climat de la Russie d'Europe. p. 280–300.

France. Académie des sciences. Comptes rendus. Tome 171. 2 août, 1920.

Zeil, G. Les tremblements de terre tectoniques et les variations de la latitude. p. 311–313. [Abstract in this REVIEW, p. 469–470.]

Great Britain. Meteorological office. Monthly meteorological charts East Indian seas.

Harries, Hy. Gales and cyclones of the Indian monsoons. Development of the monsoon conditions. May, 1920.

Harries, Hy. Some local winds of the East Indian seas. June, 1920.

Great Britain. Meteorological office. Monthly meteorological charts North Atlantic ocean.

Howard, A. G. W. Ice in the Atlantic: its origin and drift. Feb., 1920.

Howard, A. G. W. Marine meteorology. History and methods. Apr., 1920.

Smith, L. A. Brooke-. Wireless telegraphy and weather at sea. May, 1920.

Smith, L. A. Brooke-. Wireless telegraphy and weather at sea. Weather charts and how they may be constructed by navigators and used for forecasting. Sept., 1920.

Harvard college. Astronomical observatory. Annals. Cambridge, Mass. v. 83, pt. 4. 1919.

McAdie, Alexander. Quick method of measuring cloud heights and velocities. p. 162–168. [By means of an original dew-point formula with a variable constant, and nephoscope.]

McAdie, Alexander. Uniformity in aerographic notation. p. 169–177.

International institute of agriculture. International review of the science and practice of agriculture. Rome. Year 10. Mar., 1919.

Catran, F. Agricultural weather conditions on the south coast of San Domingo. p. 252–253. [Abstract from Revista de agricultura, San Domingo.]

Marcarelli, B. Injurious effect of low temperature and mist on the development of rice as connected with the propagation of weeds, in the Vercelli district, Piedmont, Italy. p. 256–258. [Abstract from Giornale di risicoltura.]

Vieules, G. Effect of cold, wind, and rust on various wheats, in France. p. 254–256. [Abstract from Revue internationale de génétique.]

Meteorological magazine. London. v. 55. Aug., 1920.

Dimensions of a waterspout. p. 152. [4,600 ft. in height, tapering from 500 ft. in diameter at the top to 150 ft. at the sea surface.]

Pick, William H. Visibility on cloudy nights. p. 137–139. [Bunsen grease spot photometer calibrated in accordance with the visibility scale.]

Nature. London. v. 105. 1920.

B., W. W. Longe-range forecasting in Java. p. 729–730. (Aug. 5.) [Review of memoir by Braak.] [Reprinted in Mo. Weather Rev., July, 1920, 48:414–415.]

Gregory, J. W. Meteorological influences of the sun and the Atlantic. p. 715–716. (Aug. 5.) [Review of work by Helland-Hansen and Nansen.] [Reprinted p. 465–466, above.]

Ackermann, Alfred S. E. Curious formation of ice. p. 741. (Aug. 12.)

Gold, E. Aerial navigation and meteorology. p. 775–776. (Aug. 19.) [Discusses merits of weather code of Annex G of the Convention for international air navigation.]

Lockyer, Sir Norman. Sir Norman Lockyer, K. C. B., F. R. S. p. 781–784. (Aug. 19.) [Obituary.]

Nature. Paris. 48 année. 1920.

Arc-en-ceil sur un arbre. p. 42. (7 août.)

Liurette, H. Le vol à voile. p. 109–112. (14 août.) [Soaring flight.]

Troller, A. L'électricité atmosphérique. p. 99–103. (14 août.) [Abstract of paper by Swann.]

Physical review. Lancaster. v. 16. Aug., 1920.

Blackwood, Oswald. Existence of homogeneous groups of large ions. p. 85–101.

Zeitschrift für Balneologie. Berlin-Wien. 12. Jahrgang. 1 März, 1920.

Kionka, H. Klimatologisches über die Thüringer Waldkurorte. p. 93–100.

SPECIAL OBSERVATIONS.

SOLOR AND SKY RADIATION MEASUREMENTS DURING AUGUST, 1920.

By HERBERT H. KIMBALL, Meteorologist.

[Solar Radiation Investigations Section, Washington, Sept. 30, 1920.]

For a description of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, **48**:225.

The monthly means and departures from normal in Table 1 indicate that solar radiation intensities were below the normal values at Madison, Wis., and Lincoln, Nebr., and above normal at Santa Fe, N. Mex. At Washington, D. C., but few observations were obtained during the month on account of unusually cloudy conditions.

Table 2 shows a decided deficiency in the total radiation received on a horizontal surface at Washington. At Madison for the month as a whole about the normal amount of radiation was received, although there was a decided deficiency during the week, August 7 to 13, inclusive.

No skylight polarization measurements were obtained at Washington during the month. Measurements obtained at Madison on 12 days give a maximum of 72 per cent on the 30th, and a mean of 58 per cent. The mean in below and the maximum about equals corresponding averages for August for Madison.

TABLE 1.—*Solar radiation intensities during August, 1920.*

[Gram-calories per minute per square centimeter of normal surface.]

WASHINGTON, D. C.

Date.	Sun's zenith distance. 8a. m.	77.8°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	77.8°	Noon.
	75th meridian time.	Air mass. A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Aug. 3	9.83				0.96	1.22					9.83
26	12.24					1.28	0.79				10.21
30	17.37				1.00		0.95				17.37
Means					(0.98)	(1.25)	(0.87)				
Departures					+0.08	+0.01	−0.09				

MADISON, WIS.

Aug. 1	7.87			1.01	1.21						7.57
2	9.83						1.17				7.29
3	7.57	0.65	0.76	0.89	1.09	1.30	0.97				8.48
5	13.13					1.08					13.61
16	12.24						0.96				13.61
17	10.97				0.71	0.98	0.79				13.13
18	11.38			0.62	0.84	1.20	0.76	0.56			10.97
19	11.81					1.13					12.24
24	8.81					1.41		1.00	0.88	0.77	6.02
25	9.83					1.30					9.14
26	8.81					1.25	1.10	0.97			10.59
30	8.48		0.95	1.05	1.21	1.38	1.15				8.81
Means		(0.65)	(0.86)	0.89	1.01	1.23	0.99	0.84	(0.88)	(0.77)	
Departures		−0.06	+0.03	−0.03	−0.08	−0.08	−0.05	−0.02	+0.07	+0.16	

* Extrapolated.

TABLE 1.—*Solar radiation intensities during August, 1920*—Continued.

LINCOLN, NEBR.

Date.	Sun's zenith distance. 8a. m.	77.8°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	77.8°	Noon.
	75th meridian time.	Air mass. A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Aug. 2	9.83					1.29	1.03	0.82	0.66		9.14
3	11.38					1.20	0.94	0.71	0.56		13.61
4	13.13			0.72	0.91						16.20
6	15.11			0.67	0.87						14.10
7	13.13		0.73	0.89	1.12	1.40					10.59
9	11.38				1.01	1.29	1.06	0.87	0.71	0.61	12.24
10	13.13		0.63	0.79	1.00						14.10
13	9.14				1.18						13.13
14	10.59				1.16	1.39					9.83
16	10.97	0.42		0.65	0.91						12.24
21	8.48		0.80	1.01	1.13	1.35	1.11	0.93	0.77	0.73	8.48
23	9.47			0.94	1.08						12.24
25	10.97						0.99	0.78			11.38
26	10.21				0.79						14.10
27	11.81				0.82						13.13
Means		(0.42)	0.72	0.81	1.00	1.32	1.03	0.82	0.68	(0.67)	
Departures		−0.28	−0.08	−0.08	−0.06	−0.02	−0.07	−0.09	−0.09	−0.04	

SANTA FE, N. MEX.

Aug. 5	9.14		0.87	1.05	1.21						9.47
6	8.18		0.97	1.10	1.26						8.81
9	9.14		1.02			1.46					9.14
10	9.83	0.91	1.01	1.13	1.29	1.51					9.83
11	9.83					1.49					6.76
14	7.29	0.92	1.03	1.15	1.29						8.81
17	8.48						1.25	1.07			8.48
18	7.87	0.89	0.98	1.09	1.26	1.47					7.57
20	8.48	0.96	1.06	1.18	1.34						7.57
23	7.87	0.93	1.02	1.14	1.31	1.54					7.57
24	6.27	0.87	1.00	1.15							5.79
25	8.18	0.87	0.98	1.08	1.24						7.57
28	3.63	1.08	1.17	1.31	1.44	1.58		1.24	1.12	1.02	3.30
29	4.17						1.37	1.22	1.11	1.02	3.99
Means		0.93	1.01	1.14	1.29	1.51	(1.31)	1.18	(1.12)	(1.02)	
Departures		+0.01	+0.03	+0.04	+0.05	+0.07	+0.03	+0.01	+0.03		

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

[Gram-calories per square centimeter.]

Week beginning.	Average daily radiation.		Average daily departure for the week.		Excess or deficiency since first of year.	
	Washington.	Madison.	Washington.	Madison.	Washington.	Madison.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
July 30	435	488	− 35	+13	+1,224	+ 835
Aug. 6	379	410	− 78	−49	+ 680	+ 491
13	362	471	− 74	+26	+ 163	+ 673
20	309	461	−106	+36	− 579	+ 925
27	418	419	+ 16	+15	− 469	+1,032

* Extrapolated.

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT, Assistant Secretary.

[Smithsonian Institution, Washington, Sept. 21, 1920.]

In continuation of preceding publications, I give in the following table the results obtained at Calama, Chile, in June and July, 1920, for the solar constant of radiation. The reader is referred to this REVIEW for February, August, and September, 1919, for statements of the arrangement and meaning of the table.

Date.	Solar const.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity.			Remarks.
					$\rho/\rho_0 C$.	V. P.	Rel. hum.	
1920 A. M.	*cal.*					*cm.*	*Per cent.*	
June 1	1.926	M_{3+}	S—	0.870	0.654	0.08	10	Some cirri in southwest. Considerable Chuqui smoke around sun preventing long method and M_3, and affecting $M_{2.5}$ and possibly M_2 Cirri appearing in west at M_9.
	1.935	M_2						
	1.933	W. M.						
2	1.931	E_9	E	.875	.758	.10	17	Possibly some smoke in early bolographs. Some smoke from kiln M_3. $M_{2.5}$ and M_2 probably affected by Chuqui smoke.
	1.949	M_3						
	1.941	$M_{2.5}$						
	1.938	M_2						
	1.938	W. M.						
3	1.954	M_3	S—	.876	.734	.05	8	Some cirri in east rapidly disappearing. Cirri in west and south.
	1.972	$M_{2.5}$						
	1.952	M_2						
	1.956	W. M.						
4	1.919	$M_{1.73}$	S—	.869	.706	.06	5	Cirri in north and east preventing earlier observations but rapidly wearing away.
	1.931	$M_{1.68}$						
	1.926	W. M.						
5	1.956	M_3	S	.874	.655	.07	10	Distant cirri in southwest. Chuqui smoke prevented long method.
	1.954	$M_{2.5}$						
	1.955	W. M.						
6	1.952	M_3	S	.872	.576	.06	8	Distant cirri in southwest. Chuqui smoke below sun in M_3.
	1.935	$M_{2.5}$						
	1.946	M_2						
	1.945	W. M.						
7	1.941	M_3	S—	.871	.549	.15	13	Distant cirri in southwest.
	1.932	$M_{2.5}$						
	1.928	M_2						
	1.933	W. M.						
8	1.935	$M_{2.5}$	S—	.872	.605	.16	14	Some Chuqui smoke in $M_{2.5}$ and possibly in M_3. Long method and M_3 prevented by smoke.
	1.919	M_2						
	1.924	W. M.						
9	1.930	$M_{2.5}$	S	.878	.716	.15	14	Chuqui smoke preventing long method and M_3.
	1.938	$M_{1.91}$						
	1.936	W. M.						
10	1.929	$M_{2.5}$	S	.880	.836	.08	8	Long method and M_3 prevented by Chuqui smoke which may have affected $M_{2.5}$ and M_2. Smoke from lime kiln in M_2.
	1.929	$M_{1.91}$						
	1.929	W. M.						
11	1.935	M_2	S	.879	.846	.08	8	Considerable Chuqui smoke preventing M_3 and $M_{2.5}$. More or less dust in air.
	1.939	$M_{1.92}$						
	1.937	W. M.						
June 12	1.903	M_3	S	0.873	0.711	*cm.* 0.05	*Per cent.* 7	Chuqui smoke prevented long method and probably affected M_3 and $M_{2.5}$.
	1.915	$M_{2.5}$						
	1.926	M_2						
	1.918	W. M.						
13	1.931	$M_{1.61}$	S	.872	.750	.05	4	Distant cirri in northeast, disappearing. Cirri preventing long method and M_3.
	1.939	$M_{1.58}$						
	1.935	W. M.						
14	1.904	$M_{1.96}$	S	.867	.626	.11	10	Few small cumuli in east. Chuqui smoke prevented long method M_3 and $M_{2.5}$.
	1.917	$M_{1.89}$						
	1.910	W. M.						
15	1.918	M_3	S	.872	.545	.19	25	Distant cumuli in northeast.
	1.930	$M_{2.5}$						
	1.926	W. M.						
P. M. 18	1.927	$M_{2.19}$	S—	.873	.575	.28	19	Cirri in north and some cumuli in south.
	1.942	$M_{2.18}$						
	1.933	W. M.						
19	1.941	$M_{1.52}$	S	.869	.674	.26	15	Scattered cirri in north, disappearing by noon.
	1.942	$M_{1.5}$						
	1.941	W. M.						
A. M. 23	1.938	$M_{1.73}$	S	.865	.667	.34	36	Some cumuli in northeast. Dust from Chuqui prevented earlier observations.
	1.942	$M_{1.67}$						
	1.939	W. M.						
24	1.932	E_9	VG+	.874	.680	.16	21	
	1.959	M_3						
	1.945	$M_{2.5}$						
	1.925	M_2						
	1.941	W. M.						
25	1.907	M_3	S—	.868	.526	.12	15	Chuqui smoke prevented M_3.
	1.924	$M_{2.5}$						
	1.914	W. M.						
26	1.949	M_3	S—	.871	.509	.17	18	Thin cirri in south.
	1.957	$M_{2.5}$						
	1.937	M_2						
	1.948	W. M.						
27	1.918	M_2	S—	.861	.509	.26	21	Cirri-cumuli in east preventing earlier observations and perhaps affecting M_3. Cirri in west.
30	1.924	E_9	VG	.862	.532	.28	39	Cloudless, except distant cumuli in east. Chuqui smoke interfered with $M_{2.5}$ and perhaps with M_3.
	1.941	M_3						
	1.918	$M_{2.5}$						
	1.944	M_2						
	1.940	W. M.						
July 1	1.921	M_3	S—	.876	.759	.08	10	Chuqui smoke prevented M_2 and $M_{2.5}$ and may have affected M_3 and $M_{1.75}$.
	1.943	$M_{1.75}$						
	1.936	W. M.						
2	1.955	M_3	S	.877	.790	.06	8	
	1.937	M_2						
	1.944	W. M.						
3	1.912	M_3	S—	.873	.696	.04	6	Chuqui smoke prevented $M_{2.5}$ and may have affected M_3 and M_2.
	1.935	M_2						
	1.929	W. M.						
4	1.936	$M_{2.12}$	S—	.874	.734	.12	13	
	1.947	M_2						
	1.942	W. M.						
5	1.956	M_3	S	.874	.715	.09	10	Chuqui smoke prevented long method; may have affected M_3.
	1.944	$M_{2.5}$						
	1.948	M_2						
	1.950	W. M.						
6	1.954	$M_{1.44}$	S—	.872	.753	.18	11	Earlier observations prevented by Chuqui smoke.
	1.940	$M_{1.42}$						
	1.949	W. M.						
7	1.934	M_3	S	.873	.623	.06	8	
	1.947	$M_{2.5}$						
	1.943	M_2						
	1.942	W. M.						

Date.	Solar const.	Method.	Grade.	Transmission coefficient at 0.5 micron	Humidity. p/p_{SC}.	Humidity. V. P.	Humidity. Rel. hum.	Remarks.
1920 A. M.	*cal.*					*cm.*	*Per cent.*	
July 8	1.938	M_3	S—	0.875	0.806	0.05	5	Chuqui smoke prevented earlier observations.
	1.953	$M_{1.91}$						
	1.945	W. M.						
9	1.942	$M_{1.82}$	S	.873	.744	.08	8	Do.
	1.939	$M_{1.73}$						
	1.941	W. M.						
10	1.931	$M_{2.5}$	S	.863	.686	.07	8	Distant cirri in southeast. Some Chuqui smoke, disappearing.
	1.923	M_2						
	1.928	$M_{1.92}$						
	1.927	W. M.						
11	1.939	$M_{2.08}$	S—	.860	.690	.15	17	Some cirri in southeast. Smoke and dust from Chuqui prevented earlier observations.
	1.937	M_2						
	1.938	W. M.						
12	1.938	M_3	S—	.866	.614	.28	41	Distant cumuli over peaks in east. Some dust from Chuqui affecting $M_{2.5}$ and preventing M_3.
	1.938	$M_{2.5}$						
	1.938	W. M.						
15	1.922	$M_{2.5}$	S—	.864	.435	.49	43	Cirri in northeast. Cumuli around east and north, sometimes forming near sun.
	1.932	$M_{1.59}$						
	1.925	W. M.						

Date.	Solar const.	Method.	Grade.	Transmission coefficient at 0.5 micron	Humidity p/p_{SC}.	Humidity V. P.	Humidity Rel. hum.	Remarks.
1920 A. M.	*cal.*					*cm.*	*Per cent.*	
July 18	1.921	M_3	S—	0.867	0.489	0.26	28	Some cirri in south.
19	1.920	M_3	S—	.866	.506	.24	29	Chuqui smoke below sun.
20	1.939	M_3	S	.869	.480	.18	20	Some cirri in south.
	1.943	M_2						
	1.942	W. M.						
21	1.953	M_3	S—	.864	.425	.19	25	Cumuli in southeast and north.
22	1.946	$M_{1.46}$	S—	.864	.602	.57	37	Cirri scattered about sky, preventing earlier observations.
24	1.943	$M_{1.82}$	S—	.867	.609	.20	16	Do.
P. M.								
25	1.936	$M_{1.86}$	S—	.870	.660	.45	25	Cirri scattered about sky, preventing A. M. observations.
A. M.								
26	1.943	M_3	S—	.868	.733	.14	14	

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL REMARKS.

The month of August was without distinctive characteristics; the areas of high and low pressure were few and not abnormal in respect to number or intensity. In fact, the contrary was true; i. e., the LOWS and HIGHS were of less than the usual August normal in number and of rather feeble development. No storm occurred that required a general issue of warnings of winds dangerous to shipping, and the issue of small-craft warnings for restricted areas was all that was required. Another abnormal meteorological phase was the entire absence of disturbances of tropical origin. The apparent reason for this is seen in the extension of the northeast trades throughout the month well southward across the Caribbean Sea and the Gulf of Mexico, probably because of the abnormal development of the oceanic high pressure to the northward of these areas. It is inferred that the "belt of calms" in which hurricanes commonly originate was at all times during the month far south, relatively speaking, of its normal position.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The distribution of the average pressure for the month was remarkable in many respects, as it was considerably above the normal at land stations on the coasts of Nova Scotia and Newfoundland, and the positive departures were unusually large in the British Isles, while the pressure was nearly normal in the West Indies and Gulf of Mexico and slightly below in the Azores.

August is usually a quiet month on the Atlantic and the month under discussion was no exception to the general rule, as few gales were reported by vessels in the steamer lanes.

The number of days with fog was apparently somewhat above the normal over the Banks of Newfoundland and considerably so in the vicinity of the British Isles, while it was not reported on more than two days in any 5° square outside of these localities.

From the 1st to the 6th the Azores HIGH was well developed, with light to moderate winds prevailing over practically the entire ocean, while during this period a few reports of fog were received from vessels on the Banks of Newfoundland and in midocean. On the 7th the barometer reading at Horta, Azores, was below the normal, and a well-developed LOW was central near latitude 42°, longitude 45°. The storm log of the American S. S. *Bellingham* is as follows: "Gale began on the 6th. Lowest barometer 29.70 inches at 8 p. m. on the 6th; position, latitude 42° 25′ N., longitude 46° 25′ W. End of gale on the 7th. Highest force of wind 9; shifts of wind near time of lowest barometer W. by S. to NW." This disturbance drifted slowly eastward and on the 8th and 9th moderate gales were encountered by vessels between the fortieth meridian and the Azores, and on the latter date the barometer at Horta registered 30 inches with a SW. wind of about 40 miles an hour. At the same time a HIGH was central off the Irish coast with pressure above normal in Icelandic waters, and in consequence southerly and southeasterly winds superseded the usual westerlies over an extensive territory between the European coast and the thirty-fifth meridian.

From the 10th to the 22d relatively high pressure prevailed over the greater part of the ocean, with slight gradients and light to moderate winds. From the 10th to the 13th fog was encountered on the Banks of Newfoundland and in British waters; on the 14th none was recorded, and from the 15th to the 18th a few fog reports were received from vessels in widely scattered positions, while from the 19th to the 22d the ocean was comparatively free.

From the 23d to the 25th the pressure was below the normal at the Azores and a HIGH was central off the European coast, while light to moderate winds prevailed over practically the entire ocean, with fog on the Banks of Newfoundland and off the coast of Scotland.

Charts IX and X give the conditions on the 26th and 27th, respectively, showing the only severe disturbance of the month. The storm log of the American S. S. *Conehatta* is as follows: "Gale began on the 25th. Lowest barometer 29.57 inches at noon on the 27th; position, latitude 42° 30′ N., longitude 46° 20′ W. End of gale on the 28th. Highest force of wind 10; wind steady from the N. to NNW." The observer on the Japanese S. S. *Tokkai Maru*, states that the lowest barometer reading was 28.90 inches at 2 p. m. on the 26th; position, latitude 46° 00′ N., longitude 46° 40′ W. He does not, however, give the highest force or shifts in wind. By the 28th this LOW had drifted slightly toward the northeast, diminishing in intensity, as only two vessels in the storm area recorded velocities as high as 40 miles an hour. On the 28th fog was reported off the coast of Nova Scotia and in the middle section of the steamer lanes, while on the 29th it was confined to northern European waters.

On the 30th and 31st there were indications of a disturbance north of the fifty-fifth parallel, and between the twenty-fifth and fortieth meridians, although not enough observations have been received from vessels in that region to determine accurately its position or extent. Regarding this LOW, the observer on the British S. S. *Melmore Head* states in his storm log: "Gale began on the 30th. Lowest barometer 29.61 inches at 4 p. m. on the 30th; position, latitude 56° 17′ N., longitude 32° 20′ W. End of gale on the 31st. Highest force of wind 8; shifts of wind near time of lowest barometer SSW. to WSW." On the 30th and 31st fog was observed on the Banks of Newfoundland and off the British coast, the greater part of the steamer routes being free.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

August is usually a quiet month on the North Pacific Ocean, except that the typhoon season is at its height in Asiatic waters. During this month on an average three or four of these tropical storms occur each year.

In the August just past two typhoons prevailed, as indicated by reports thus far received, one at the beginning, the other at the end of the month. The early part of the history of the first belongs to July, the latter part of the second to September.

On July 31 warnings were broadcast by meteorological services in the Far East giving information of the presence of a depression having its center in latitude 23° N., longitude 133° E. By August 2 the center had moved

to latitude 28° N., longitude 131° E. On the latter date the depth of the center and the direction of movement of depression, as received radio by one of the reporting ships of the Weather Bureau were, respectively, at 6 a. m., 29.29 inches, NW.; at noon, 29.37 inches, NW.; at 6 p. m., 29.31 inches, N.W. It was doubtless this storm that affected shipping to the east of Japan on the 4th and 5th.

On August 4 the Japanese S. S. *Celebes Maru*, Capt. J. Kurimura, from Yokohama for San Francisco, began to feel the influence of this depression. Mr. J. Nakagawa, second officer and observer, states that at 3 p. m. the barometer was falling rapidly and the sky assuming a threatening appearance. The barometer continued to fall until 3.30 a. m. of the 5th, at which time there was a whole gale, with occasional squalls of hurricane force, and a very high sea. The vessel was laboring and plunging violently and shipping dangerous seas all the time. The lowest barometer occurred at 4 a. m. of the 5th, 29.09 inches, uncorrected. At that hour there was a SSE. gale, force 10. Position of ship, latitude 38° 50′ N., longitude 148° 50′ E. The shifts of the wind during the storm were ENE., E., SE., SSE., S.; highest force, 12, S.

Regarding the typhoon at the close of the month but little is known as yet. Press dispatches would indicate that it was of a severe character. At Manila several vessels in the harbor sustained damage and a number of lighters were wrecked. The following notes regarding these losses were taken from the *New York Maritime Register:*

Montrose (Br. S. S.)—London, September 2:

A typhoon occurred at Manila on August 31 and the following vessels in port received damage: Steamer *Montrose* (Br.) from New York via Shanghai, etc., had sternpost broken; steamer *Colusam* from Calcutta, etc., for San Francisco, broke her moorings—only a small portion of her cargo is damaged; steamer *Egremont Castle* (Br.) from New York via Hongkong, etc., was slightly damaged.

Eastern Mariner (S. S.)—Manila, September 2:

Steamer *Eastern Mariner*, from New York via Karatsu, etc., with oil, is aground in harbor here after encountering a typhoon; believed not badly damaged. A number of lighters were wrecked in the typhoon and the native crews are missing.

Aside from these storms of tropical origin in Asiatic waters the month was a quiet one. In a total of 134 reports that have been examined, representing 1,267 daily observations, gales were reported on but 26 days, as follows: Force 7 on 10 days; force 8 on 12 days; force 9 on 2 days; force 10 on 1 day; force 12 on 1 day. The last-named gale was that experienced by the *Celebes Maru*, already referred to. Fog was encountered on 104 days, mainly in the form of occasional banks. Of the reports examined, 22 were from vessels on coastwise routes, principally between Panama and Pacific coast ports of the United States and Canada.

Pressure was generally below normal throughout the month on the Asiatic side and during the first half in Bering Sea and the Gulf of Alaska. In the latter waters an effect of this distribution was to cause persistent easterly winds. Mr. Perry Christiansen, observer on the American S. S. *Northwestern* (Seattle for Alaskan ports, Capt. Wm. Jensen), states that throughout the voyage lasting from July 30 to August 15 there were continuous strong SE. to NE. winds on Prince William Sound and across the Gulf of Alaska, with heavy rain. The wind at times almost reached the force of a gale. Lowest barometer reading, 29.28 inches, corrected.

Following the depression of the 4th and 5th east of Japan, to which reference has been made, a strong anticyclone moved southward over Kamchatka and spread slowly eastward. Central readings on the 5th and 6th reached 30.50 inches. By the 12th this high pressure was south of the Aleutians and beginning to affect the region of the permanent North Pacific anticyclone to the eastward, readings as high as 30.60 and 30.62 inches (normal central pressure, 30.30 inches) being reported on the 17th and 18th, respectively, to the northeastward of the Hawaiian Islands. Winds reaching gale force prevailed along the North American coast on these dates. The influence of this high pressure was more or less apparent until the close of the month. During the period from the 16th to the 20th another anticyclone developed over the western portion of the ocean and moved eastward, its center approximately following the fortieth parallel. This also had the effect of reinforcing the permanent anticyclone and readings above the normal for the month were reported on a number of days, as high as 30.56 inches on the 25th.

An incident of the fog conditions on the California coast, associated with this high pressure, was the grounding of the Dutch S. S. *Arakan*, near Point Reyes Light on August 31. An account of this grounding appears on page 466.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

Canada.—Regina, Saskatchewan, Aug. 5.—For the second time within a few days a cyclone [tornado] swept through the Estevan district. Several buildings were blown down and the temporary structures at the fair grounds were demolished.

No loss of life has been reported. Telephone wires for miles around were blown down and there was no direct communication with the district.—*Washington Star*, Aug. 5, 1920.

Alaska.—Dawson, Yukon, Aug. 10—* * * Millions of feet of timber has been destroyed by forest fires which swept both banks of the Peel River for 160 miles. The season has been unusually dry and the river is so low that the steamer *Thistle* is stalled in Ross River.—*Washington Star*, Aug. 10, 1920.

Japan.—Tokio, Aug. 20.—Serious floods continue in northern and southern Japan. * * * In the Iwate prefecture 11 persons have been drowned and 4,600 houses submerged, 100 of them being destroyed. Fifty bridges also have gone down, and crops and roads have been ruined. * * *

The town of Thukumo, on the island of Shikoku, virtually has been destroyed. Seventy bodies have been recovered in the muddy streets there. * * *

There has been considerable damage at Osaka. * * * —*Washington Star*, Aug. 21, 1920.

Philippine Islands.—Manila, Aug. 17.—Collapse of a mountain top on this island, in a recent storm, buried an entire Igorotte village under hundreds of feet of earth, blotting out the lives of 70 natives. * * * —*Washington Star*, Aug. 20, 1920.

India.—London, Aug. 11.—Simla reports that abnormal monsoonal winds have caused floods throughout the country. A number of villages in Bengal were swept away, and large areas of country in various districts destroyed. In Calcutta many streets were deeply flooded and heavy damage done to goods and property.—*The Samoa Times*, Apia, Samoa, Aug. 14, 1920.

Chile.—Santiago, Aug. 13.—The first snowstorm here in more than a decade occurred yesterday, about 6 inches falling. In the mountains the storm assumed blizzard proportions, interrupting communications between the coast and the cities of the central provinces.—*Washington Post*, Aug. 14, 1920.

DETAILS OF THE WEATHER OF THE MONTH IN THE UNITED STATES.

CYCLONES AND ANTICYCLONES.

By E. H. BOWIE, Supervising Forecaster.

In respect to the movements of systems of low pressure across the North American Continent, the first of these made its appearance in the vicinity of southeastern Alaska July 31 and was 8 days in reaching the Atlantic coast; the 2d appeared in the same region on the 4th and reached the Atlantic States on the 11th to 13th; the 3d was from the 10th to the 16th in crossing; the 4th was from the 16th to 23d in crossing; and the 5th was from the 26th to August 1 in crossing. These systems of low pressure referred to are general depressions of the barometer of considerable geographic areas within which cyclonic storms usually have their origin. One of these low pressure systems may cross the Continent without any well-defined cyclonic development, or one may cross the Continent and have one or more distinct cyclones from within it. Moreover, the system of low pressure may be traced over a longer period of time than the average cyclone.

LOWS.

	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mountains.	Colorado.	Texas.	East Gulf.	South Atlantic.	Central.	Total.
August, 1920	7.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	2.0	11.0
Average number, 1892-1912	4.2	0.6	0.3	0.9	1.0	0.2	0.0	0.1	1.0	8.3

Anticyclones.—The number of HIGHS was slightly above the average. The table shows the number of HIGHS by types.

HIGHS.

	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain region.	Hudson Bay.	Total.
August, 1920	3.0	0.0	4.0	0.0	1.0	8.0
Average number, 1892-1912	1.9	0.2	3.0	0.9	0.8	6.8

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Weather Bureau, Washington, Oct. 1, 1920.]

PRESSURE AND WINDS.

Barometric pressure during August, 1920, exhibited no marked fluctuations, and the movements of the high and low areas, usually but poorly defined during this month, were frequently uncertain. In fact, no well-defined storm areas showed continuous movements over extended tracks, and high-pressure areas remained stagnant for long periods without material change.

Despite almost continuous precipitation over much of the country east of the Mississippi Valley during long periods, the average pressure for the month was well above the normal, and it was above in practically all other portions of the country as well as over most districts of Canada. The highest pressures were, as usual, observed along the Atlantic and Pacific coasts, but the departures from normal were generally no greater than over the interior districts. As compared with the normal, pressure was highest over the Canadian Maritime Provinces and lowest along the immediate Pacific coast and over the Canadian Northwest.

Thunderstorms were of frequent occurrence and some local high winds attended their development and movement, but otherwise the winds were light, and velocities of 50 miles or more per hour were reported mainly from coast districts. As usual for a summer month, the winds were from southerly points over the Plains region and thence eastward, except in portions of the Lake region and upper Mississippi Valley, where they were locally from northerly points. In the Plateau and Pacific Coast States, winds were mostly from westerly points, although frequently modified by local topography

TEMPERATURE.

Over the territory from the Rocky Mountains eastward the month was notably free from sharp changes in temperature, and periods of decided warmth, usually experienced in August, were the exception. In fact, from the standpoint of temperature the month was almost wholly pleasant over all eastern and central districts. To westward of the Rocky Mountains temperature changes were more pronounced, particularly so in the Great Valley of California, where the first half of the month was markedly warm, the maximum temperatures at certain points rising to 100° or more daily. At Sacramento excessive heat continued from July 29 to August 18, a period not equaled in the previous history of the station. The latter part of the month, however, had more moderate temperatures, and in some localities, notably at Fresno, Calif., and in portions of Arizona, the temperatures were unusually low for August.

For the month as a whole the average temperature was below normal over all interior portions of the country and over the greater part of the South as well. Along portions of the middle Atlantic coast the temperatures were almost continuously below the normal throughout the month. At Atlantic City, N. J., only the last three days of the month were warmer than the normal. This condition was probably due largely to the low temperature of the adjacent ocean waters, referred to in the July REVIEW.[1] The temperature of the ocean water at this

[1] P. 424.

place during August was nearly 10° below the normal. In connection with this the observer states that northeast to southeast winds for the first five days of the month failed to cause any increase in the surface-water temperature, but that prevailing southwest winds from the 7th to 17th were accompanied by lower water temperatures, notably on the 16th and 17th, when the abnormally low temperature of 56° was reached.

Over the more northeastern States the average temperature for the month was above normal, and the month was distinctly warm as a whole along the northern border from Lake Superior westward and generally over the Pacific Coast States.

High temperatures were the exception over central and eastern districts, and in only a few sections did the maximum values reach 100°. Over the Plateau and Pacific States high temperatures were observed on frequent dates, but mostly during the first half of the month. In Oregon a maximum temperature of 110° was observed, in Idaho 111°, in Nevada 113°, in Arizona 116°, and California reported a temperature of 124°.

Minimum temperatures were in a few instances as low as, or lower than, previously reported in August, and in the far western districts they occurred mostly during the last decade. In the region of the Great Lakes they were below freezing at exposed points on the 22d, and temperatures near freezing, with light frost, were reported at exposed points in the western Plains region on the 13th. In the mountain districts temperatures below freezing were reported in all the States, the lowest, 14°, occurring in Montana.

PRECIPITATION.

August was distinctly a rainy month from the middle and southern Plains region eastward to the Atlantic coast. In portions of the East Gulf States and generally over the Atlantic coast districts as far north as New York, the month was almost continually cloudy or rainy. At some reporting stations not a single clear day was observed during the entire month. The number of cloudy days was far above normal—in some cases greater than ever before observed in any month—and rain continued daily for periods of 10 to 15 days or more. In the Rocky Mountain States and thence west to the Pacific coast precipitation was likewise more frequent than usual, and the monthly totals were generally above normal.

From the Dakotas eastward to the Great Lakes, including portions of Iowa, Illinois, Indiana, and generally over New York and New England, precipitation was less frequent during the month, and the total falls were in most sections less than normal.

The distribution was uniformly heavy, 6 to 8 or 10 inches, from central Texas eastward to the south Atlantic coast and over the Appalachian Mountain districts and thence to the coast as far north as eastern Pennsylvania and New Jersey. In portions of this region rain was of almost daily occurrence and the total falls frequently exceeded 10 inches, the maximum amount for the month, 25 inches, occurring in western North Carolina. Heavy falls were likewise recorded in many other districts east of the Rocky Mountains, but the distribution was less uniform than in the area previously mentioned. West of the Rocky Mountains precipitation was quite unevenly distributed, as is usual for this month, but in favored localities considerable rain occurred, some unusual falls being reported from central California, where rain rarely occurs in August.

RELATIVE HUMIDITY.

The cloudy, rainy conditions existing throughout the month over southern and eastern districts are reflected in the humidity values of the same regions, which were everywhere in excess of normal, and decidedly so in the west Gulf and southern Plains States. From the Dakotas eastward to the Great Lakes, where precipitation was generally deficient, the relative humidity was likewise less than normal, and it was more or less deficient in the Pacific Coast States.

SEVERE STORMS.

The damaging storms of the month were confined to those of the thunderstorm type, and the areas of damage were usually not extensive.

A severe thunderstorm, with exceptionally heavy rain, occurred on the 10th in the vicinity of Sand Lake, Averell Park, and Snyders Corners, N. Y. Some estimates of the amount of rainfall were in excess of 10 inches, but no estimates of damage are at hand.

In the vicinity of Providence, R. I., a severe windstorm on the 15th caused considerable damage.

In the vicinity of Springer, N. Mex., on the 27th a small tornado is reported to have caused considerable damage to buildings over a path several miles long.

In the vicinty of Hartford, Conn., a severe hail and windstorm on the 31st caused damage to growing crops, mostly tobacco, and to other property, estimated at $2,000,000. This storm also extended into Massachusetts and Rhode Island, doing considerable damage to crops and buildings. Concerning this storm in eastern Massachusetts, the following note was received from Cooperative Observer H. W. Cushing:

> This storm was not as severe in Hingham as in Weymouth. The effects in Hingham were confined to the blowing down of one barn and uprooting of trees in the village cemetery at Liberty Plain, South Hingham, about 1½ miles from my house. Also, marble gravestones were broken off and blown over, and the cemetery tool house was carried into the next field. In the adjoining town of Weymouth the damage was much greater, as several buildings and trees were blown over or moved from their foundations. The path of destruction was very narrow, hardly more than 100 feet, and therefore difficult to decide whether cyclonic in character, or direct blow from the course of the storm, although buildings and trees were blown flat in the storm's direction.
>
> I was not an observer of the destructive part of the storm, as my house was at quite a distance.

STORMS AND WARNINGS—WEATHER AND CROPS.

STORMS AND WEATHER WARNINGS.

EDWARD H. BOWIE, Supervising Forecaster.

Washington forecast district.—The month was marked by an unusual number of showery and rainy days and by small fluctuations in temperature and moderate winds. The number of forecasts issued of showers, rains, and thunderstorms was above the normal for this month. No general storm warnings were issued, but small-craft warnings were issued on the 22d for the Middle Atlantic and New England coasts and on the 29th for the Great Lakes. On the 25th and 26th advices concerning the wind and weather conditions attending a disturbance over the ocean were sent to Atlantic ports and to vessels at sea by radio. This disturbance apparently had its origin off the Carolina coast on the 25th. Frost warnings were issued for northern Michigan on the 21st and 22d.

Chicago forecast district.—Frost warnings were issued for the cranberry bogs of central Wisconsin on the 1st for all the bogs in the State on the 21st, and for all except the Shell Lake section in northwestern Wisconsin on the 22d. These warnings were fully verified. Heavy frost occurred on the 23d in the bogs of central Wisconsin.

Warnings were issued for western and central Montana and northwestern Wyoming on the 30th, and for Montana, Wyoming, the western portions of the Dakotas, and western Nebraska on the 31st. These warnings were only partially verified.

The special fire-weather forecasts for Montana were sent to the district forester at Missoula, Mont., daily throughout the month.

Upon telegraphic request of the secretary of the Missouri State Fair Association, Sedalia, Mo., the following special forecast was issued on the 12th:

Fair weather with moderate temperature Friday, Saturday, and Sunday. Indications point to rising temperature and fair weather first part next week.

The Illinois State Fair was held at Springfield from August 20 to 28, and the following special forecasts were issued at the request of the section director:

August 19: "Showers Friday and Friday night, followed by a period of fair weather and moderate temperature for several days."

August 23: "Fair weather next three days. Temperature will rise slowly beginning Tuesday."

August 26.—"Fair weather is probable Friday and Saturday with continued moderate temperature."

All of the above special forecasts were well verified, as is indicated by the following editorial from the *Illinois State Journal:*

WEATHER BUREAU MAKES GOOD.

Friends of the Illinois State Fair take off their hats to the Weather Bureau. They are grateful for the accuracy of the special predictions which it made prior to and during the expositions.

Weather indications for the opening of the fair were not particularly favorable. The Bureau, however, issued a reassuring forecast, on the strength of which prospective visitors who feared that they would encounter bad weather took heart and braved the clouds.

They were not disappointed. Nor were others who later were guided by supplemental predictions of perfect weather for the exposition.

The Weather Bureau comes in for much adverse criticism during the course of a year. Its errors of judgment are like the errors of a ball player, never failing to attract attention. It gets little enough credit for the number of predictions which prove true. When it performs as well as it did during the fair, it is entitled to flowers and the thanks of those who, depending on its forecasts, visited the fair.

C. L. Mitchell, Meteorologist.

New Orleans forecast district.—No warnings were issued or required. However, southeast winds were locally high at Corpus Christi, Tex., on the afternoon of the 28th, when the monsoon tendency prevailing on the Texas coast was reinforced by the passage of a disturbance whose center was far to the northward.—*R. A. Dyke, Meteorologist.*

Denver forecast district.—No important low barometer areas crossed the district during August, and the month was unusually dry.

The prevalence of moderately high barometric pressure was attended by abnormally cool weather in the greater part of the district.

No warnings were issued, except on the 31st. On the morning of that date an anticyclone occupied the northern and middle Rocky Mountain regions, with the barometer nearly five-tenths of an inch above the normal in Idaho and western Montana. Warnings of frost were issued for high districts in Utah and localities in eastern Colorado and the northern portion of Arizona and New Mexico.—*F. W. Brist, Meteorologist.*

San Francisco forecast district.—Southwest storm warnings were ordered at Washington and Oregon stations on the 27th and 29th and verified.

Fire-weather warnings were issued for Washington, Oregon, and Idaho on the 5th, 11th, 19th and 23d. The warnings covered periods of three or four days and were amply justified. At the request of the forest supervisor at Missoula, Mont., daily forecasts of wind and weather for Idaho were telegraphed to him from the 11th to the 28th, inclusive.

Special forecasts of fog along the coast from San Francisco to San Diego were requested by the Naval Air Service on the 11th and 13th. The forecasts were verified.—*G. H. Willson, Meteorologist.*

RIVERS AND FLOODS.

FLOODS DURING AUGUST.

By H. C. FRANKENFIELD, Meteorologist.

Moderate floods occurred in the James River, August 21 and August 29, and in the rivers of South Carolina at about the same time. The Saluda River also reached flood stage at Pelzer, S. C., on August 11.

There were unusual crop losses in the lowlands of the Congaree and Wateree Rivers, and some live stock losses were suffered in the swamp regions of the Santee River.

Flood stages were reached in the Apalachicola River at River Junction, Fla., in the Tennessee River at Riverton, Ala., in the Mad River at Springfield, Ohio, in the Trinity River at Dallas, Tex., and in the Rio Grande at Rio Grande City, Tex.

The flood in progress at the end of July in the Columbia River at Marcus, Wash., had subsided by August 3.

Estimated Loss by Floods.

River and district.	Farms, buildings, machinery, live stock, etc.	Suspension of business.	Value of warnings.	Tangible property, roads, bridges, etc.	Crops.	
					Matured.	Prospective.
Tennessee:						
Cairo, Ill.	.....	$1,000	.....	.....	.....	$120,000
Congaree and Wateree:						
Columbia, S. C.	$3,000	2,700	$76,000	.....	$30,000	25,000
Total.	3,000	3,700	76,000	.....	30,000	145,000

Flood stages during month of August, 1920.

River and district.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.					
James:	*Feet.*			*Feet.*	
Columbia, Va.	18	21	21	25.2	21
Do.	18	29	29	19.0	29
Richmond, Va.	10	21	21	11.0	21
Do.	10	29	29	11.0	29
Roanoke:					
Randolph, Va.	21	21	21	21.2	21
Weldon, N. C.	30	22	22	31.3	22
Santee:					
Rimini, S. C.	12	12	(1)	16.2	31
Ferguson, S. C.	12	14	(1)	13.7	25
Catawba:					
Catawba, S. C.	12	28	28	14.6	28
Wateree:					
Camden, S. C.	24	21	21	24.6	21
	24	28	30	28.6	29
Congaree:					
Columbia, S. C.	15	28	28	19.5	28

Flood stages during month of August, 1920—Continued.

River and district.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE—continued.					
Broad:	*Feet.*			*Feet.*	
Blairs, S. C.	15	19	20	16.4	19
	15	27	28	22.6	27
Saluda:					
Pelzer, S. C.	7	11	12	7.0	11, 12
Do.	7	19	19	7.0	19
Chappells, S. C.	14	20	21	14.6	21
Apalachicola:					
River Junction, Fla.	12	15	24	13.4	19, 22
MISSISSIPPI DRAINAGE.					
Mad:					
Springfield, Ohio.	10	22	22	10.8	22
Tennessee:					
Riverton, Ala.	32	18	21	33.2	20
WEST GULF DRAINAGE.					
Trinity:					
Dallas, Tex.	25.0	30	(1)	27.3	31
Rio Grande:					
Rio Grande City, Tex.	15.0	25	25	15.0	25
PACIFIC DRAINAGE.					
Columbia:					
Marcus, Wash.	24.0	(2)	3	28.5	3 15–19

[1] Continued into September. [2] Continued from July. [3] July.

MEAN LAKE LEVELS DURING AUGUST, 1920.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Sept. 7, 1920.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during August, 1920:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York.	602.93	581.01	572.65	245.62
Above or below—				
Mean stage of July, 1920.	−0.01	−0.02	+0.02	−0.08
Mean stage of August, 1919.	+0.37	−0.13	−0.49	−1.71
Average stage for August, last 10 years.	+0.35	+0.15	0.00	−0.92
Highest recorded August stage.	−1.00	−2.50	−1.46	−2.64
Lowest recorded August stage.	+1.33	+1.16	+1.27	+1.27
Average relation of the August level to—				
July level.	.....	−0.10	−0.20	−0.30
September level.	.....	+0.20	+0.20	+0.40

[1] Lake St. Clair's level: In August, 575.66 feet.

EFFECT OF WEATHER ON CROPS ARD FARMING OPERATIONS, AUGUST, 1920.

By J. WARREN SMITH, Meteorologist.

[Weather Bureau, Washington, Oct. 1, 1920.]

There was considerable interruption to farm work during much of August in the South and in most of the Middle and South Atlantic Coast States by frequent rains, and the totals for the month were unusually heavy in much of that area. Otherwise the weather was generally favorable for outdoor operations and all seasonal farm work made satisfactory progress, especially that of harvesting and thrashing the winter grain crops. At the close of the month the harvest of winter grain was nearing completion in the late northwestern districts and that of spring grain was progressing satisfactorily. The preparation of soil for winter-wheat seeding made generally satisfactory progress, with ample soil moisture in nearly all sections. Plowing was general in Illinois at the close of the month, was well advanced in Missouri, and further along than in an average year in Kansas. Some wheat was sown in the northwestern portion of the belt.

At the beginning of the month growing crops, especially corn, needed moisture rather badly in much of Missouri, Kentucky, and Illinois, and droughty conditions had become severe in some interior sections by the middle of the month. These conditions were largely relieved, however, soon thereafter by good rains in the central Great Plains, the lower Missouri, and the central and upper Mississippi Valleys, resulting in a marked improvement in the corn crop in those sections. Corn continued satisfactory development in most of the South and in the Atlantic Coast States, but in some north-central districts the lack of moisture and the cool weather resulted in deterioration. At the close of the month the condition of the crop continued above the average in all of the principal producing States, except in Illinois, and there was a rather marked improvement during the month in most sections, particularly in the central Great Plains, where the Bureau of Crop Estimates reported a condition of 140 to 190 per cent of the 10-year average, with an improvement during the period of 20 to 25 per cent.

There was considerable interruption to rice harvest in the lower Mississippi Valley and the west Gulf districts, and some rice was damaged by too much rain. Grain sorghums made satisfactory development in the lower Great Plains but were considerably later than usual in Kansas, where there was some fear as to maturity before frost. While buckwheat continued in better condition than usual in the principal producing States, there was some falling off in its condition, particularly in parts of New England, New Jersey, and Maryland, where the decline during the month ranged from 9 to 15 per cent, as reported by the Bureau of Crop Estimates.

Much cloudy, showery weather prevailed in the cotton belt after the first decade of the month and rainfall was frequently excessive. The result was generally unfavorable for cotton and the crop deteriorated in many sections of the belt, with much insect damage, particularly from Louisiana eastward. For the month as a whole, the weather was fairly favorable in the Carolinas, Tenesssee, Arkansas, and Texas, and at its close the condition of cotton in those States was near the average, while the condition was fair to very good in Oklahoma. As a result of the continued unfavorable weather, however, the crop deteriorated in other portions of the belt and at the close of the month was in mostly poor condition, particularly in Louisiana, Mississippi, Alabama, Georgia, and Florida. By the end of the month picking was becoming general in Georgia and southern Alabama and was begun in South Carolina, but this work was being delayed in many southern sections of the belt by continued wet weather.

In considering the combined condition of all crops by States at the close of the month, and the change in condition during August, it is noted that a material improvement was recorded in nearly all central districts, where rainfall was generous during the month. A deterioration was shown from Louisiana eastward, where excessive rains occurred, and also from the upper Lake region westward, where rainfall was deficient. In parts of the latter area, the decline was as much as 10 per cent, while in the central and southern Great Plains, where moisture conditions were more favorable, an improvement, ranging from 5 to 18 per cent, was recorded.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by section, August 1920.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	77.6	−2.0	Camp Hill	98	30	Oneonta	52	25	6.83	+2.48	Tuskegee	11.33	Cochrane	2.96
Arizona	76.7	−1.2	Mohawk	116	12	Fort Valley	31	28	2.24	−0.17	Superior	7.16	Aztec	T.
Arkansas	76.8	−2.6	Marked Tree	102	6	Dutton	46	4	4.08	+0.27	Higden	8.55	Danville	1.14
California	73.2	+0.4	Greenland Ranch	124	7	Portola	30	19	0.25	+0.17	Indio	3.61	63 stations	0.00
Colorado	62.0	−2.6	3 stations	98	7†	Crested Butte	17	23	2.33	+0.38	Fremont Exp. Sta.	6.39	Durango	0.31
Florida	80.7	−0.6	De Land	101	22	Marianna	60	11	6.67	−0.50	De Funiak Springs	14.39	Merritts Island	1.91
Georgia	78.0	−1.3	Statesboro	101	1	Blue Ridge	54	5	7.81	+2.31	Glennville	16.67	Alapaha	3.39
Hawaii (July)	74.9	+0.7	Mahukona	95	25	Waimea	50	2	3.63	−1.65	Glenwood	14.42	4 stations	0.00
Idaho	66.5	+0.7	Glenns Ferry	111	15	2 stations	19	19†	0.89	+0.37	Blackfoot Dam	3.03	Buhl	0.00
Illinois	72.6	−1.4	2 stations	99	6	Henry	40	24	2.91	−0.44	Salem	10.23	Pontiac	0.40
Indiana	71.4	−1.8	Hobart	99	20	Wheatfield	39	23	3.15	−0.17	Jeffersonville	6.73	Frankfort	0.65
Iowa	69.3	−2.5	2 stations	98	10†	2 stations	39	24	3.35	−0.33	Britt	8.52	Burlington	0.44
Kansas	72.9	−4.3	Hutchinson	102	1	3 stations	38	13	4.50	+1.35	Walnut	13.19	Scott City	0.96
Kentucky	73.4	−2.3	Hopkinsville	98	6	2 stations	43	2†	5.83	+2.27	Woodbury	10.96	Oliver	1.79
Louisiana	80.5	−1.2	Calhoun	101	17	Calhoun	54	4	6.66	+1.10	Ludington	12.87	Robeline	1.38
Maryland-Delaware	73.6	−0.1	2 stations	95	8	Oakland, Md	42	3†	7.01	+2.58	Woodstock, Md	11.16	Chewsville, Md	2.95
Michigan	66.0	−0.4	2 stations	97	6†	Ewen	29	22	2.76	+0.09	Morenci	7.25	Bloomingdale	0.37
Minnesota	67.0	+0.4	Warren	101	18	Grand Rapids	30	22	1.80	−1.58	Tyler	4.65	Crookston	0.47
Mississippi	78.7	−1.7	Poplarville	99	22	2 stations	52	3	5.06	+0.58	Woodville	10.74	Crenshaw	1.44
Missouri	73.1	−3.0	Caruthersville	102	6	Palmyra	43	24	4.78	+0.89	Osceola	10.47	Maryville	0.96
Montana	66.1	+1.7	Knowlton	106	16	Bowen	14	31	1.25	+0.07	Bennett's Ranch	4.26	Crow Agency	0.00
Nebraska	69.7	−3.0	Weeping Water	100	16	Nenzel	33	13	3.77	+0.97	Springfield	13.29	Alliance	1.57
Nevada	71.0	−0.2	Logandale	113	7	2 stations	28	19†	0.88	+0.51	Lahontan	2.97	Elko	T.
New England	69.4	+2.8	Vernon, Vt	102	11	Somerset, Vt	35	20	3.56	−0.24	Farmington, Me	7.20	Rockport, Mass	0.92
New Jersey	72.3	+0.3	2 stations	94	17	Charlotteburg	42	4	6.10	+1.31	Moorestown	10.60	Elizabeth	2.94
New Mexico	68.1	−2.1	Alamagordo	104	2	Winsors Ranch	29	28	2.92	+0.32	Hobbs	9.17	Aztec	0.17
New York	69.0	+1.7	Gabriels	95	8	2 stations	35	24	3.65	−0.21	2 stations	9.10	Appleton	0.91
North Carolina	74.6	−1.0	Greenville	100	30	Jefferson	49	5	7.94	+2.30	Marion	25.00	Nashville	3.00
North Dakota	68.7	+3.3	Arnegard	108	17	Minto	28	22	1.57	−0.71	Bottineau	4.83	Pembina	0.14
Ohio	70.3	−1.4	Chilo	95	5	2 stations	40	2†	4.36	+0.94	Circleville	9.99	Vickery	1.37
Oklahoma														
Oregon	67.2	+1.9	2 stations	110	14†	Blitzen	16	20	1.15	+0.66	Government Camp	2.79	Choloquin	T.
Pennsylvania	70.2	+0.2	Lancaster	95	9	West Bingham	37	3†	4.66	+0.64	Lancaster	9.29	Ridgway	1.93
Porto Rico	78.9	−0.3	2 stations	95	13†	Jaynya	58	2	7.04	−0.39	Maricao	13.93	Destino	2.00
South Carolina	77.7	−1.1	Blackville	100	1	Santuck	56	27	8.08	+1.95	Santuck	15.40	Trenton	2.81
South Dakota	69.2	−1.2	Cottonwood	108	9	2 stations	33	20†	1.93	−0.59	Custer	5.00	Redig	0.44
Tennessee	74.6	−1.9	2 stations	97	6†	Waynesboro	44	3	7.25	+3.10	Sewanee	17.71	Kenton	1.59
Texas	79.7	−2.9	3 stations	106	1†	Dalhart	48	14	5.63	+3.03	Gatesville	14.50	Brownsville	0.00
Utah	68.6	−0.4	St. George	107	6†	Blacks Fork	21	31	1.58	+0.40	Cottonwood Nursery	3.62	Lucin	0.05
Virginia	73.1	−1.4	West Point	97	16	Burkes Garden	41	3	7.12	+2.32	Fredericksburg(near)	11.95	Norfolk	3.83
Washington	66.8	+1.2	Conconenlly	109	13	Colfax	28	31	1.44	+0.67	Snoqualmee Pass	6.20	Port Townsend	0.31
West Virginia	71.1	−0.6	2 stations	95	8†	Holcomb	42	3	4.25	+0.37	Stony River Dam	9.28	Lost Creek	1.69
Wisconsin	65.9	−1.0	Richland Center	99	10	Prentice	27	22	2.75	−0.65	Fond du Lac	5.78	Tomahawk	0.46
Wyoming	62.8	−0.9	Sheridan Field Sta	102	17	South Pass City	16	29	1.29	+0.23	Foxpark	4.04	Opal	0.03

* For description of tables and charts, see this REVIEW, January, 1920, p. 54.

† Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, August, 1920.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.											Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.						Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Direction.	Date.						
	Ft.	*Ft*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
New England.							**69.3**	**+ 2.3**											**84**	**3.08**	**− 0.8**										**6.2**		
Eastport	76	67	85	29.98	30.06	+0.10	60.8	+ 1.1	83	9	69	49	5	53	26	57	56	89	2.10	− 1.2	10	5,118	s.	28	e.	25	10	10	11	6.0	0.0	0.0
Greenville, Me	1,070	6	....	28.93	30.08	.....	66.6	.....	88	9	78	42	21	56	35	.....	.....	.....	12	4.61	.....	12	.....	.....	.....	.....	.....	.....	.....	.....	17	4	10	.....	0.0	0.0
Portland, Me	103	82	117	29.96	30.08	+ .10	68.0	+ 1.8	91	8	74	55	21	62	30	62	60	83	3.83	+ 0.3	13	4,655	s.	26	w.	14	10	9	12	5.7	0.0	0.0
Concord	288	70	79	29.76	30.07	+ .09	71.4	+ 4.8	91	8	82	48	21	61	30	.....	.....	.....	11	2,395	se.	31	w.	31	4	16	11	6.6	0.0	0.0
Burlington	404	11	48	29.62	30.05	+ .08	69.3	+ 3.2	90	8	79	46	24	60	29	.....	.....	.....	8	2.37	− 1.6	8	5,412	s.	33	s.	22	9	12	10	5.4	0.0	0.0
Northfield	876	12	60	29.15	30.08	+ .10	66.6	+ 3.7	88	8	79	40	24	54	38	62	60	86	12	2.19	− 1.7	12	3,452	s.	24	s.	21	6	17	8	6.2	0.0	0.0
Boston	125	115	188	29.93	30.06	+ .07	72.0	+ 3.1	93	8	79	56	21	65	25	65	62	77	11	2.32	− 1.7	11	5,410	sw.	26	nw.	8	8	11	12	6.1	0.0	0.0
Nantucket	12	14	90	30.06	30.07	+ .08	68.6	+ 0.6	79	8	74	54	20	63	21	66	65	93	12	4.43	+ 1.4	12	9,690	sw.	30	sw.	15	7	6	18	6.8	0.0	0.0
Block Island	26	11	46	30.04	30.08	+ .09	69.3	+ 0.6	79	31	74	60	24	65	16	66	65	93	11	2.57	− 0.9	13	9,356	sw.	50	nw.	31	7	6	18	6.8	0.0	0.0
Providence	160	215	251	29.90	30.07	+ .08	72.3	+ 1.3	91	9	81	51	21	64	30	66	63	80	11	3.17	− 0.9	11	6,175	sw.	53	nw.	31	8	9	14	6.0	0.0	0.0
Hartford	159	122	140	29.90	30.07	+ .08	72.4	+ 3.5	89	8	81	51	21	64	31	66	63	78	11	3.45	− 1.1	11	4,400	s.	29	sw.	31	7	8	16	6.4	0.0	0.0
New Haven	106	74	153	29.96	30.07	+ .08	72.0	+ 1.9	90	17	79	55	21	65	24	66	64	79	12	2.69	− 2.3	12	5,513	sw.	31	sw.	31	8	11	12	5.8	0.0	0.0
Middle Atlantic States.							**72.6**	**− 2.0**											**84**	**6.13**	**+ 1.7**										**7.0**		
Albany	97	102	115	29.95	30.05	+ .07	72.0	+ 2.5	88	9	81	51	24	63	27	65	62	76	12	2.71	− 1.2	12	4,223	s.	22	s.	9	6	18	7	5.3	0.0	0.0
Binghamton	871	10	84	29.14	30.06	+ .07	70.0	+ 2.5	88	8	80	47	2	60	33	.....	.....	.....	14	3.72	+ 0.4	14	2,802	e.	26	nw.	7	5	11	15	6.7	0.0	0.0
New York	314	414	454	29.73	30.06	+ .06	72.8	+ 0.6	85	17	79	57	3	66	19	67	64	80	14	4.91	+ 0.4	14	8,421	s.	56	nw.	31	1	11	19	7.3	0.0	0.0
Harrisburg	374	94	104	29.68	30.07	+ .06	72.4	+ 0.3	89	8	80	55	3	65	23	66	63	79	21	8.84	+ 4.6	21	3,545	s.	27	w.	31	3	6	22	7.5	0.0	0.0
Philadelphia	117	123	190	29.95	30.07	+ .07	74.3	+ 0.5	88	31	81	58	3	68	20	69	67	83	18	7.31	+ 2.7	18	5,897	e.	26	s.	14	3	6	22	7.9	0.0	0.0
Reading	325	81	98	29.72	30.06	.....	73.2	.....	89	17	81	54	3	65	25	66	64	79	15	4.34	− 0.1	15	3,718	se.	37	n.	31	3	7	21	7.9	0.0	0.0
Scranton	805	111	119	29.23	30.08	+ .08	70.8	+ 1.5	88	12	80	49	3	61	28	64	62	79	14	3.33	− 0.9	14	3,688	n.	30	sw.	31	2	12	17	7.5	0.0	0.0
Atlantic City	52	37	48	30.00	30.05	+ .05	69.6	− 3.0	88	31	74	56	3	65	17	67	66	90	19	5.65	+ 1.4	19	5,174	sw.	20	ne.	4	7	10	14	6.2	0.0	0.0
Cape May	18	13	49	30.07	30.09	+ .09	70.5	− 2.8	88	31	75	59	3	66	17	67	66	91	19	7.78	+ 3.5	19	5,318	s.	22	ne.	4	6	5	20	7.3	0.0	0.0
Sandy Hook	22	10	57	30.05	30.07	.....	72.6	.....	86	8	78	60	3	67	17	68	67	87	19	5.33	.....	19	8,126	ne.	43	nw.	17	0	17	14	7.0	0.0	0.0
Trenton	190	159	183	29.86	30.06	.....	72.4	.....	88	17	80	55	3	65	23	67	65	84	19	7.08	+ 1.7	19	6,797	e.	37	w.	7	3	9	19	7.5	0.0	0.0
Baltimore	123	100	113	29.94	30.06	+ .05	74.8	+ 0.1	91	8	82	58	3	68	20	69	66	81	16	9.47	+ 5.3	16	4,565	ne.	26	n.	17	5	8	18	7.1	0.0	0.0
Washington	112	62	85	29.94	30.05	+ .04	74.8	+ 0.3	92	17	82	56	3	67	23	69	67	83	16	4.70	+ 0.3	16	3,615	n.	27	nw.	1	5	11	15	6.7	0.0	0.0
Lynchburg	681	153	188	29.34	30.07	+ .05	73.7	− 1.1	90	30	82	57	4	66	23	67	66	85	16	6.76	+ 2.5	15	3,889	e.	25	nw.	17	4	17	10	6.1	0.0	0.0
Norfolk	91	170	205	29.97	30.07	+ .07	76.8	+ 0.1	91	17	83	64	25	70	20	71	69	85	14	3.83	− 2.1	14	8,118	s.	39	sw.	10	3	9	19	7.2	0.0	0.0
Richmond	144	11	52	29.92	30.06	+ .05	75.2	− 2.3	92	17	83	57	4	68	24	70	68	87	18	8.69	+ 4.3	18	4,919	s.	28	s.	9	5	4	22	7.8	0.0	0.0
Wytheville	2,304	49	56	27.75	30.06	+ .05	68.5	− 2.0	83	30	76	52	3	61	23	64	62	88	20	8.99	+ 4.4	20	2,917	w.	18	nw.	18	5	18	8	5.9	0.0	0.0
South Atlantic States.							**77.5**	**− 0.4**											**85**	**6.62**	**+ 0.4**										**6.8**		
Asheville	2,255	70	84	27.79	30.08	+ .06	70.0	− 0.5	84	20	77	56	5	63	21	65	64	88	23	7.09	+ 2.3	23	4,164	se.	33	s.	8	0	11	20	7.8	0.0	0.0
Charlotte	779	55	62	29.24	30.06	+ .04	74.9	− 1.7	90	31	83	62	4	67	22	69	68	85	21	8.91	+ 3.4	21	2,790	sw.	18	nw.	1	2	6	23	7.7	0.0	0.0
Hatteras	11	12	50	30.06	30.06	+ .06	77.6	− 0.6	88	31	83	68	3	72	13	74	73	89	11	3.88	− 2.0	11	8,171	s.	39	sw.	6	4	13	14	6.6	0.0	0.0
Manteo	12	5	42	.....	.....	.....	76.9	.....	94	18	85	64	1	68	.....	.....	.....	.....	9	3.23	.....	9	.....	sw.	.....	.....	.....	9	10	12	.....	0.0	0.0
Raleigh	376	103	110	29.67	30.06	+ .05	75.8	− 1.8	92	31	84	59	4	68	21	70	69	85	13	3.80	− 2.1	13	4,540	sw.	29	se.	8	3	9	19	7.3	0.0	0.0
Wilmington	78	81	91	30.00	30.08	+ .08	77.6	0.0	92	1	85	64	4	71	24	73	71	86	16	5.23	− 1.3	16	4,568	sw	24	ne.	20	4	16	11	6.2	0.0	0.0
Charleston	48	11	92	30.01	30.06	+ .05	80.2	− 0.1	95	31	86	66	4	74	22	75	73	82	13	7.02	0.0	13	6,466	s.	34	se.	5	4	11	16	6.9	0.0	0.0
Columbia, S. C	351	41	57	29.69	30.07	+ .06	78.6	− 0.9	95	1	87	63	5	70	23	71	69	84	14	7.68	+ 0.9	17	3,944	s.	27	sw.	6	2	11	18	7.4	0.0	0.0
Greenville, S. C	1,039	113	122	28.98	30.05	.....	74.3	.....	89	31	81	61	6	67	23	69	67	87	23	5.96	.....	23	4,600	ne.	28	se.	8	1	10	20	7.5	0.0	0.0
Augusta	180	62	77	29.86	30.05	+ .04	79.4	+ 0.5	96	1	88	61	4	70	26	72	71	79	13	4.87	− 0.7	13	3,263	s.	30	s.	6	2	15	14	6.5	0.0	0.0
Savannah	65	150	194	29.99	30.06	+ .05	80.0	+ 0.6	95	31	88	66	5	72	24	74	72	84	15	10.27	+ 2.8	15	6,283	s.	32	ne.	7	8	11	12	6.1	0.0	0.0
Jacksonville	43	209	245	30.01	30.06	+ .05	80.6	+ 0.5	94	26	88	68	20	74	26	74	73	85	20	7.46	+ 1.2	20	7,045	se.	51	sw.	4	10	17	4	4.8	0.0	0.0
Florida Peninsula.							**81.7**	**− 1.1**											**76**	**4.98**	**− 2.0**										**4.9**		
Key West	22	10	64	30.01	30.03	+ .05	82.6	− 1.2	90	5	88	70	7	77	19	75	72	73	13	5.15	+ 0.5	13	6,504	e.	35	sw.	15	9	18	4	4.6	00	00
Miami	25	71	79	30.03	30.06	.....	80.0	.....	88	25	86	69	15	74	16	75	72	75	18	4.12	− 3.5	18	5,533	e.	36	e.	15	13	10	8	4.6	00	00
Sand Key	23	39	72	29.98	30.01	+ .03	81.0	− 2.0	87	4	84	68	6	78	16	75	73	73	11	2.61	.....	11	8,750	e.	40	s.	15	13	15	3	4.3	00	00
Tampa	35	79	92	30.02	30.05	+ .05	81.4	0.0	93	12	89	69	4	74	20	75	73	83	16	5.66	− 2.9	16	3,820	ne.	36	sw.	4	3	21	7	6.2	00	00
East Gulf States.							**78.5**	**− 0.8**											**83**	**6.98**	**+ 2.1**										**6.9**		
Atlanta	1,174	190	216	28.85	30.07	+ .06	75.1	− 1.0	88	1	83	61	25	68	22	69	67	84	17	10.02	+ 5.5	17	5,648	s.	27	nw.	1	4	3	24	8.0	00	00
Leesburg	279	10	55	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Macon	370	78	87	29.66	30.05	+ .04	78.5	− 0.3	94	1	87	64	25	70	24	71	69	82	18	5.32	+ 1.1	18	3,585	s.	26	s.	6	4	8	19	7.0	00	00
Thomasville	273	49	58	29.76	30.04	+ .04	80.0	− 1.0	94	31	89	66	5	71	22	73	71	83	21	4.96	− 0.1	21	2,382	sw.	22	sw.	26	0	18	13	7.2	00	00
Pensacola	56	149	185	29.97	30.03	+ .05	79.2	− 1.8	91	31	84	69	7	74	16	74	72	82	17	11.56	+ 4.4	17	7,477	s.	39	s.	6	1	13	17	7.5	00	00
Anniston	741	9	57	29.28	30.06	+ .07	76.1	− 0.3	90	31	86	55	25	67	29	.....	.....	.....	19	5.93	+ 1.4	19	2,745	s.	17	sw.	13	6	13	12	6.0	00	00
Birmingham	700	11	48	29.31	30.06	+ .07	77.2	− 2.6	92	31	86	58	25	68	26	70	68	84	13	9.09	+ 4.6	13	3,634	s.	21	se.	8	4	10	17	6.8	00	00
Mobile	57	125	161	29.96	30.02	+ .04	80.2	+ 0.5	93	31	87	69	26	74	20	74	73	85	18	7.78	+ 1.0	18	5,379	sw.	46	se.	17	2	14	15	6.9	00	00
Montgomery	223	100	112	29.80	30.04	+ .04	78.8	− 0.9	93	31	87	65	25	71	21	72	70	83	15	6.91	+ 2.7	15	3,832	s.	34	n.	22	5	13	13	6.1	00	00
Corinth	469	6	....	.....	.....	.....	77.7	.....	95	6	88	54	3	67	34	.....	.....	.....	12	3.38	.....	12	.....	s.	.....	.....	.....	6	21	4	.....	00	00
Meridian	375	85	93	29.63	30.02	+ .04	78.1	− 0.4	92	1	87	62	25	70	22	71	70	84	15	6.92	+ 3.4	15	2,984	sw.	22	se.	16	5	14	12	6.2	00	00
Vicksburg	247	65	74	29.75	30.03	+ .05	78.8	+ 0.8	91	31	87	63	3	71	24	72	71	87	17	4.07	+ 0.5	10	3,715	se.	25	nw.	26	2	15	14	6.8	00	00
New Orleans	53	76	84	29.96	30.01	+ .03	81.3	+ 0.3	94	29	88	73	9	75	18	75	73	80	19	4.18	− 1.4	19	2,595	sw.	27	sw.	26	4	11	16	7.2	00	00
West Gulf States.							**79.5**	**− 1.4**											**80**	**4.66**	**+ 0.7**										**6.1**		
Shreveport	249	77	93	29.74	30.00	+ .03	79.8	− 1.6	95	1	88	64	4	71	23	72	70	79	9	2.82	+ 0.6	9	3,847	s.	25	w.	22	10	16	5	4.8	00	00
Bentonville	1,303	11	44	28.66	29.99	+ .02	73.4	− 3.1	89	8	83	55	22	63	29	.....	.....	.....	18	6.30	+ 2.3	18	2,551	s.	18	n.	25	11	12	8	4.8	00	00
Fort Smith	457	79	94	29.51	29.98	+ .01	78.4	− 1.0	96	31	88	61	4	68	27	70	66	73	9	1.68	− 2.0	9	4,563	e.	26	w.	29	8	13	10	5.6	00	00
Little Rock	357	139	147	29.64	30.01	+ .03	77.4	− 1.8	92	31	86	61	24	69	26	70	68	80	10	3.33	− 0.3	10	4,355	s.	36	nw.	21	8	17	6	5.2	00	00
Brownsville	57	4	26	.....	.....	.....	86.2	.....	99	24	96	73	23	76	25	.....	.....	.....	0	0.00	.....	0	.....	se.	.....	.....	.....	.....	.....	.....	.....	00	00
Corpus Christi	20	69	77	29.95	29.97	+ .04	82.8	+ 0.7	94	1	88	72	14	78	18	77	75	82	4	1.44	− 0.8	4	10,373	se.	41	s.	28	9	12	10	5.7	00	00
Dallas	512	109	117	29.44	29.98	.....	78.4	.....	101	1	86	64	23	70	28	.....	.....	.....	18	6.50	.....	18	5,056	s.	27	nw.	24	3	19	9	6.3	00	00
Fort Worth	670	106	114	29.25	29.95	+ .01	78.1	− 4.8	100	1	86	64	15	70	26	71	68	78	12	4.22	+ 2.4	12	5,701	s.	30	nw.	9	3	15	13	6.6	00	00
Galveston	54	106	114	29.95	30.01	+ .05	82.4	− 0.2	90	1	87	72	25	78	16	76	74	81	10	2.65	− 2.4	10	6,208	se.	25	se.	12	3	21	7	6.1	00	00
Groesbeck	461	11	56	29.48	29.95	.....	79.2	.....	97	1	88	63	25	70	26	73	72	86	12	6.45	.....	12	5,421	s.	34	sw.	16	4	12	15	6.6	00	00
Houston	138	111	121	29.84	29.98	.....	81.7	.....	95	1	90	69	15	74	22	.....	.....	.....	17	11.26	.....	17	4,068	se.	33	se.	16	2	19	10	6.3	00	00
Palestine	510	64	72	29.47	30.00	+ .03	78.6	− 1.9	92	20	87	62	25	70	24	72	70	85	14	7.63	+ 5.4	14	3,952	s.	25	ne.	24	1	11	19	7.7	00	00
Port Arthur	34	58	66	29.94	29.98	.....	80.6	.....	90	1	87	71	25	75	19	75	73	82	17	4.78	.....	17	4,768	s.	25	w.	27	3	17	11	6.9	00	00
San Antonio	701	119	132	29.24	29.96	+ .03	82.9	+ 0.9	98	2	93	69	15	73	26	73	69	74	7	2.26	− 0.4	7	4,943	se.	36	se.	31	9	19	3	5.0	00	00
Taylor	582	55	63	29.40	30.01	+ .06	80.8	− 0.9	98	1	90	66	25	72	25	.....	.....	.....	9	4.25	+ 1.8	9	5,009	s.	25	s.	28	4	8	19	7.5	00	00

TABLE 1.—*Climatological data for Weather Bureau stations, August, 1920*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.						Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.							
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	° *F*		° *F*	° *F*		° *F*	° *F*				° *F*	° *F*	%	*In.*	*In.*		*Miles*									*0–10*	*In.*	*In.*
							72.8	**− 1.5**													**78**	**5.28**	**+ 1.8**									**6.2**		
Chattanooga	762	189	213	29.27	30.07	+0.07	74.4	− 2.1	89	31	82	59	25	67	25	68	67	85	12.36	+ 8.6	23	4,097	sw.	38	nw.	31	3	8	20	7.4	00	00
Knoxville	996	102	111	29.01	30.05	+ .04	73.7	− 1.0	88	30	82	59	24	66	24	67	66	84	11.33	+ 7.3	18	3,759	sw.	26	s.	7	2	6	23	8.2	00	00
Memphis	399	76	97	29.63	30.05	+ .07	77.4	− 1.8	92	6	85	61	23	70	22	70	67	75	2.32	− 0.9	9	4,663	sw.	34	nw.	28	9	14	8	5.3	00	00
Nashville	546	168	191	29.47	30.05	+ .05	75.0	− 2.8	90	5	83	55	24	67	24	68	66	80	6.85	+ 3.4	19	4,618	ne.	52	w.	31	8	9	14	6.3	00	00
Lexington	989	193	230	29.00	30.04	+ .03	72.2	− 2.4	88	5	80	53	23	64	26	....	....	....	6.71	+ 3.1	15	7,188	sw.	35	nw.	12	6	9	16	6.6	00	00
Louisville	525	219	255	29.47	30.05	+ .05	73.6	− 1.0	91	6	82	54	23	65	28	67	64	77	4.78	+ 1.3	12	6,176	s.	39	w.	21	8	13	10	5.2	00	00
Evansville	431	139	175	29.58	30.04	+ .05	75.4	− 1.4	94	6	85	56	23	66	29	37	64	74	6.31	+ 3.1	11	5,685	sw.	46	w.	31	6	19	6	5.3	00	00
Indianapolis	822	194	230	29.17	30.05	+ .05	72.0	− 1.6	91	6	81	49	23	63	28	64	60	70	1.85	− 1.5	8	6,264	ne.	44	se.	7	11	9	11	5.5	00	00
Royal Center	730	11	55	29.25	30.04	.....	68.8	.....	92	6	80	42	23	57	34	62	59	74	1.42	.....	7	5,067	n.	33	w.	31	12	8	11	4.9	00	00
Terre Haute	575	96	129	29.40	30.01	.....	72.9	.....	93	6	83	50	23	63	29	64	59	68	2.89	.....	6	4,965	ne.	28	w.	30	9	13	9	5.6	00	00
Cincinnati	628	11	51	29.37	30.04	+ .03	71.2	− 0.4	91	5	80	50	2	62	30	....	64	80	6.10	+ 2.8	13	3,915	ne.	25	se.	7	9	10	12	5.9	00	00
Columbus	824	179	222	29.20	30.06	+ .05	70.2	− 2.8	86	5	78	53	3	62	28	65	62	80	4.09	+ 0.9	12	5,827	n.	28	sw.	21	6	12	13	6.2	00	00
Dayton	899	181	216	29.07	30.01	.....	71.1	− 2.5	90	5	80	51	2	62	32	64	61	77	2.64	− 0.4	13	5,405	ne.	26	nw.	31	7	17	7	5.5	00	00
Elkins	1,947	59	67	28.06	30.06	+ .04	68.1	− 0.3	85	8	77	46	3	59	33	63	62	88	3.33	− 0.3	18	2,085	se.	17	w.	31	0	11	20	8.0	00	00
Parkersburg	638	77	84	29.41	30.06	+ .05	72.9	− 0.4	88	8	82	52	3	64	27	66	64	80	2.65	− 0.9	10	2,825	se.	22	sw.	7	7	6	18	6.6	00	00
Pittsburgh	842	353	410	29.16	30.05	+ .04	71.6	− 0.9	86	7	80	51	2	64	22	64	61	75	2.53	− 0.6	12	6,459	sw.	34	nw.	30	6	8	17	6.2	00	....
Lower Lake Region.							**69.8**	**+ 0.2**													**74**	**2.62**	**− 0.4**									**5.7**		
Buffalo	767	247	280	29.23	30.05	+ .06	70.2	+ 1.4	84	12	76	54	1	64	24	63	60	73	1.77	− 1.2	8	8,009	s.	42	sw.	30	3	12	16	6.8	0.0	0.0
Canton	448	10	61	29.57	30.03	.....	69.0	+ 1.2	90	9	79	46	24	59	31	....	....	....	1.94	− 0.8	9	4,847	sw.	29	sw.	21	13	11	7	4.6	0.0	0.0
Oswego	335	76	91	29.68	30.04	+ .05	68.8	0.0	82	6	76	51	3	62	21	63	60	77	1.95	− 0.7	9	5,043	s.	26	nw.	31	7	11	13	6.0	0.0	0.0
Rochester	523	86	102	29.50	30.07	+ .08	70.3	+ 2.0	88	6	78	50	24	62	24	63	59	71	1.51	− 1.4	10	4,220	sw.	28	w.	30	6	12	13	6.4	0.0	0.0
Syracuse	597	97	113	29.43	30.07	+ .08	70.5	+ 1.9	87	8	79	50	3	62	26	....	....	....	2.58	− 0.8	9	5,461	s.	34	nw.	31	5	18	8	5.8	0.0	0.0
Erie	714	130	166	29.28	30.04	+ .03	70.3	+ 0.4	86	21	77	52	3	64	22	64	61	75	2.34	− 0.9	7	7,977	se.	35	s.	20	5	17	9	5.8	0.0	0.0
Cleveland	762	190	201	29.24	30.05	+ .04	69.4	− 1.0	87	21	76	51	3	63	22	64	61	76	2.33	− 0.8	8	7,664	ne.	62	nw.	10	5	13	13	6.4	0.0	0.0
Sandusky	629	62	103	29.37	30.04	+ .03	70.8	− 0.7	88	21	77	53	3	64	22	....	....	....	1.71	− 1.7	9	6,573	s.	44	nw.	10	7	14	10	5.5	0.0	0.0
Toledo	628	208	243	29.38	30.05	+ .05	69.7	− 1.2	91	6	78	50	23	62	23	63	60	77	5.85	+ 3.2	10	7,303	n.	32	n.	16	11	13	7	4.7	0.0	0.0
Fort Wayne	856	113	124	29.14	30.05	.....	69.4	− 1.7	91	6	79	47	23	60	27	62	58	72	3.08	.....	8	4,328	e.	30	sw.	7	10	11	10	5.2	0.0	0.0
Detroit	730	218	245	29.28	30.06	+ .05	69.4	− 0.5	89	6	77	51	23	62	22	62	59	74	4.20	+ 1.4	9	6,421	n.	40	w.	13	8	12	11	5.8	0.0	0.0
Upper Lake Region.							**66.0**	**− 0.2**													**76**	**2.12**	**− 0.8**									**4.4**		
Alpena	609	13	92	29.41	30.08	+ .08	64.1	+ 0.3	82	30	72	42	23	56	27	60	58	84	1.59	− 1.8	9	6,308	se.	29	sw.	30	11	11	9	5.3	0.0	0.0
Escanaba	612	54	60	29.40	30.06	+ .07	63.0	− 1.5	78	16	71	44	22	55	23	58	56	79	2.11	− 1.5	9	5,935	s.	33	ne.	12	17	10	4	3.2	0.0	0.0
Grand Haven	632	54	89	29.36	30.03	+ .04	66.2	− 1.6	86	19	75	45	23	57	26	60	56	72	0.99	− 1.6	4	5,985	nw.	29	s.	30	16	10	5	4.1	0.0	0.0
Grand Rapids	707	70	87	29.29	30.05	+ .05	69.9	− 0.1	90	6	81	46	2	59	29	62	57	66	0.76	− 1.8	5	2,942	ne.	16	nw.	31	13	8	10	4.8	0.0	0.0
Houghton	684	62	99	29.30	30.06	+ .09	63.0	− 0.3	85	19	73	44	22	53	30	....	....	....	1.21	− 1.7	7	5,477	e.	28	n.	12	18	8	5	2.9	0.0	0.0
Lansing	878	11	62	29.12	30.05	.....	67.9	− 0.1	90	6	80	43	2	56	33	61	58	80	2.00	− 0.6	6	2,525	n.	16	nw.	13	8	15	8	5.9	0.0	0.0
Ludington	637	60	66	29.36	30.05	.....	64.2	.....	84	19	73	42	23	56	26	60	58	82	2.33	.....	8	5,389	n.	28	n.	21	19	9	3	3.1	0.0	0.0
Marquette	734	77	111	29.28	30.09	+ .11	62.8	− 0.7	85	15	71	47	22	55	29	57	54	77	3.50	+ 0.6	11	5,445	nw.	32	s.	4	14	8	9	4.6	0.0	0.0
Port Huron	638	70	120	29.36	30.05	+ .05	67.4	+ 0.1	88	6	74	47	3	60	26	62	60	81	5.51	+ 2.9	11	6,112	ne.	35	n	21	9	16	6	4.8	0.0	0.0
Saginaw	641	69	77	29.36	30.06	.....	67.4	.....	88	6	77	44	2	58	28	61	58	76	1.75	− 1.1	7	4,554	ne.	27	sw.	30	8	15	8	5.4	0.0	0.0
Sault Ste. Marie	614	11	52	29.38	30.07	+ .08	64.5	+ 3.9	85	7	75	42	24	54	35	59	56	78	1.87	− 1.3	7	3,814	se.	24	nw.	1	13	10	8	4.5	0.0	0.0
Chicago	823	140	310	29.17	30.04	+ .04	71.0	− 0.2	90	5	76	59	23	66	25	62	58	68	3.16	+ 0.3	9	6,349	ne.	31	sw.	20	14	9	8	4.4	0.0	0.0
Green Bay	617	109	144	29.39	30.05	+ .06	66.9	− 0.1	89	11	76	48	22	58	26	59	55	72	1.80	− 1.3	7	6,362	n.	35	sw.	30	12	11	8	4.9	0.0	0.0
Milwaukee	681	125	139	29.31	30.05	+ .05	67.7	− 1.0	88	5	75	48	22	60	25	61	57	73	2.03	− 0.8	7	5,715	ne.	29	ne.	21	14	11	6	4.2	0.0	0.0
Duluth	1,133	11	47	28.84	30.04	+ .07	63.6	− 1.3	86	4	72	45	22	55	28	58	55	76	1.44	− 2.1	5	7,149	ne.	29	nw.	6	18	5	8	3.5	0.0	0.0
North Dakota.							**69.6**	**+ 2.8**													**62**	**1.24**	**− 1.1**									**2.7**		
Moorhead	946	8	57	29.00	30.00	+ .04	68.4	+ 2.5	98	9	82	40	21	54	41	60	55	70	1.33	− 1.8	7	5,239	se.	27	s.	18	26	3	2	1.5	0.0	0.0
Bismarck	1,674	8	57	28.22	29.98	+ .04	70.4	+ 2.3	98	17	84	38	21	56	41	58	51	59	0.59	− 1.4	6	7,343	se.	35	se.	28	22	4	5	2.5	0.0	0.0
Devils Lake	1,482	11	44	28.40	29.95	+ .01	68.4	+ 3.3	96	9	82	39	21	55	38	58	52	63	2.21	− 0.6	6	6,833	s.	32	s.	18	22	6	3	2.5	0.0	0.0
Ellendale	1,457	10	56	28.45	29.99	.....	66.9	.....	93	9	82	37	21	51	41	59	54	69	0.74	.....	7	8,916	s.	49	sw.	10	16	10	5	3.6	0.0	0.0
Grand Forks	835	12	89	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Williston	1,878	41	48	27.95	29.88	− .05	71.0	+ 3.1	102	17	85	43	21	57	50	57	48	51	0.81	− 0.5	3	5,575	se.	38	nw.	17	17	10	4	3.3	0.0	0.0
Upper Mississippi Valley.							**71.4**	**− 1.5**													**71**	**2.62**	**− 0.6**									**4.5**		
Minneapolis	918	102	208	29.03	30.00	.....	70.0	.....	93	10	80	50	21	60	27	....	....	....	1.14	− 2.6	6	6,795	s.	39	sw.	29	19	7	5	3.5	0.0	0.0
St. Paul	837	236	261	29.13	30.03	+ .06	69.2	+ 0.3	91	10	80	49	22	59	28	....	....	....	0.96	− 2.5	6	6,711	se.	45	sw.	29	19	8	4	2.8	0.0	0.0
La Crosse	714	11	48	29.27	30.03	+ .05	68.2	− 1.8	92	10	80	46	23	57	30	....	....	....	2.25	− 1.2	8	2,319	sw.	15	se.	4	19	4	8	3.7	0.0	0.0
Madison	974	70	78	29.02	30.04	+ .05	68.8	− 0.8	90	11	78	50	23	59	28	61	56	69	2.61	− 0.6	8	4,576	n.	26	sw.	30	13	11	7	4.5	0.0	0.0
Wausau	1,247	4	....	28.73	30.04	.....	65.6	.....	91	10	78	39	22	33	37	....	....	....	2.08	.....	7	....	n.	....	....	....	14	6	11	4.4	0.0	0.0
Charles City	1,015	10	49	28.98	30.04	+ .07	67.7	− 3.0	90	10	80	46	23	56	31	60	57	74	4.46	+ 1.0	10	2,960	se.	20	nw.	20	13	13	5	4.5	0.0	0.0
Davenport	606	71	79	29.38	30.03	− .05	72.6	− 0.4	93	6	83	51	23	63	28	63	58	67	2.67	− 1.0	7	3,603	e.	20	sw.	20	13	12	6	4.5	0.0	0.0
Des Moines	861	84	97	29.12	30.02	+ .05	71.4	− 1.6	93	4	82	53	22	61	30	62	58	69	2.11	− 1.5	7	3,590	n.	23	n.	20	15	8	8	4.6	0.0	0.0
Dubuque	698	81	96	29.31	30.05	+ .07	69.6	− 2.4	91	11	80	49	23	59	29	62	59	74	3.44	+ 0.4	11	3,042	nw.	24	se.	20	14	12	5	4.5	0.0	0.0
Keokuk	614	64	78	29.37	30.03	+ .05	73.4	− 1.2	93	6	83	51	24	64	28	64	59	66	0.88	− 2.4	6	3,568	ne.	35	w.	31	6	15	10	5.9	0.0	0.0
Cairo	356	87	93	29.64	30.01	+ .02	75.1	− 1.9	90	6	83	57	24	67	26	68	65	78	2.48	− 0.4	12	4,396	ne.	34	n.	31	9	7	15	5.9	0.0	0.0
Peoria	609	11	45	29.38	30.04	+ .05	72.2	− 0.3	94	6	84	43	24	60	30	64	60	73	1.87	− 1.1	8	2,760	s.	17	s.	20	17	10	4	3.9	0.0	0.0
Springfield, Ill	644	10	91	29.34	30.01	+ .02	72.9	− 1.1	94	6	82	50	24	63	29	64	60	72	4.60	+ 1.8	10	3,953	se.	30	nw.	30	10	10	11	5.6	0.0	0.0
Hannibal	534	74	109	29.45	30.02	+ .04	72.4	− 2.6	93	6	83	48	24	62	30	....	....	....	3.05	− 0.3	9	4,242	sw.	27	s.	6	14	8	9	4.7	0.0	0.0
St. Louis	567	265	303	29.42	30.02	+ .03	75.1	− 2.1	92	6	84	56	23	67	23	65	60	66	4.16	+ 1.5	10	6,404	s.	46	sw.	8	9	16	6	4.6	0.0	0.0
Missouri Valley.							**71.6**	**− 2.3**													**69**	**3.68**	**− 0.3**									**3.8**		
Columbia, Mo	781	11	84	29.18	30.00	+ .03	73.0	− 1.7	92	18	83	48	24	63	28	....	....	....	3.50	+ 0.5	7	3,789	se.	26	n.	31	12	10	9	5.0	0.0	0.0
Kansas City	963	161	181	28.99	30.00	+ .03	73.7	− 2.1	93	8	82	57	22	65	24	65	60	66	3.11	− 1.6	10	6,130	se.	28	sw.	31	16	10	5	4.1	0.0	0.0
St. Joseph	967	11	49	28.98	30.00	.....	73.3	.....	94	10	84	51	22	63	29	64	59	68	1.95	.....	7	4,220	se.	35	w.	31	20	5	6	3.7	0.0	0.0
Springfield, Mo	1,324	98	104	28.64	30.02	+ .05	72.4	− 2.4	88	7	81	56	24	64	25	66	63	78	6.31	+ 2.0	13	5,584	se.	40	n.	31	14	14	3	3.7	0.0	0.0
Iola	984	11	50	28.96	29.99	+ .03	74.0	− 2.3	96	7	86	54	23	62	32	....	....	....	7.55	+ 4.1	11	3,149	e.	24	n.	25	8	15	8	5.5	0.0	0.0
Topeka	987	92	107	....	....	....	72.6	− 5.4	94	8	83	53	23	62	31	....	....	....	4.98	+ 0.7	10	4,933	s.	33	nw.	31	15	11	5	4.1	0.0	0.0
Drexel	1,299	10	53	28.63	30.00	.....	69.8	.....	90	10	81	49	22	59	30	63	60	76	4.82	.....	9	5,086	se.	28	se.	28	18	5	8	4.2	0.0	0.0
Lincoln	1,189	11	84	28.75	29.99	+ .04	71.8	− 2.5	93	10	83	52	22	61	35	62	58	67	3.69	0.0	7	5,109	se.	28	n.	28	16	8	7	4.3	0.0	0.0
Omaha	1,105	115	122	28.85	30.01	+ .05	72.6	− 1.8	92	10	82	54	22	63	25	63	59	67	2.78	− 0.8	7	4,303	se.	37	n.	20	18	7	6	4.2	0.0	0.0
Valentine	2,598	47	54	27.32	30.00	+ .06	70.2	− 1.1	92	3	83	38	13	57	39	58	52	61	1.73	− 1.1	8	6,823	s.	34	s.	10	20	7	4	2.9	0.0	0.0
Sioux City	1,135	94	164	28.85	30.02	+ .07	69.8	− 2.8	90	9	80	48	22	59	29	62	58	69	4.30	+ 1.3	10	6,758	s.	39	nw.	6	20	5	6	3.2	0.0	0.0
Huron	1,306	59	74	28.64	30.02	+ .07	68.6	− 0.4	90	4	81	45	22	56	32	60	55	68	1.74	− 0.9	5	5,483	se.	38	nw.	3	25	3	3	2.1	0.0	0.0
Pierre	1,572	70	75	28.33	29.97	+ .03	70.8	− 2.3	96	17	83	47	30	58	34	62	57	68	2.07	+ 0.1	5	6,044	e.	38	w.	29	23	4	4	2.2	0.0	0.0
Yankton	1,233	49	57	28.70	30.00	+ .05	69.7	− 3.1	91	3	82	48	22	58	32	....	....	....	2.35	− 0.8	7	4,454	se.	28	nw.	10	18	7	6	3.4	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, August, 1920*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.											Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.						Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F*		°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	%	*In.*	*In.*		*Miles*					*0–10*	*In.*	*In.*
Northern Slope.							**65.8**	**— 0.4**												**56**	**1.58**	**— 0.3**								**3.5**		
Billings	3,140	5					69.6	+ 2.7	102	25	84	44	21	55	44	57	49	57	0.81	— 0.4	9	4,492	sw.	36	nw.	2	21	7	3	2.8	0.0	0.0
Havre	2,505	11	44	27.35	29.93	+0.02	66.7	+ 0.6	95	15	80	38	31	53	38	51	41	48	0.79	+ 0.1	8	5,880	sw.	43	sw.	25	14	12	5	3.8	0.0	0.0
Helena	4,110	87	112	25.85	29.97	+ .03	63.6	+ 0.7	93	8	77	35	29	50	38	52	42	54	2.61	+ 1.7	8	4,071	nw.	28	n.	10	21	6	4	3.0	0.0	0.0
Kalispell	2,973	48	56	26.94	29.94	+ .01																										
Miles City	2,371	26	48																													
Rapid City	3,259	50	58	26.65	30.00	+ .07	69.3	+ 0.5	91	17	82	46	31	56	38	56	48	53	1.30	— 0.8	8	5,055	w.	28	se.	17	19	8	4	3.0	0.0	0.0
Cheyenne	6,088	84	101	24.13	29.99	+ .07	62.8	— 3.0	81	24	75	41	29	51	33	52	46	64	1.32	— 0.2	13	6,606	w.	46	w.	10	11	12	8	4.8	0.0	0.0
Lander	5,372	60	68	24.74	29.99	+ .07	65.2	— 0.5	91	16	81	34	31	49	42	51	41	48	0.23	— 0.3	4	3,858	sw.	38	w.	17	15	13	3	4.0	0.0	0.0
Sheridan	3,790	10	47	26.14	29.98		67.0		98	17	84	32	29	50	47	54	46	58	0.68		7	3,126	s.	34	se.	25	19	8	4	3.2	0.0	0.0
Yellowstone Park	6,200	11	48	24.60	30.02	+ .09	59.0	— 1.9	86	15	74	29	31	44	39	47	39	56	0.87	— 0.2	9	5,062	s.	40	nw.	2	11	17	3	4.2	0.0	0.0
North Platte	2,821	11	51	27.15	30.03	+ .09	70.0	— 2.2	91	16	83	40	13	57	41	60	55	68	4.73	+ 2.3	9	4,276	se.	37	n.	8	20	7	4	3.0	0.0	0.0
Middle Slope.							**72.1**	**— 3.2**												**68**	**3.33**	**+ 0.9**								**4.7**		
Denver	5,292	106	113	24.84	30.01	+ .09	67.8	— 2.6	88	10	79	48	29	57	32	55	47	56	1.27	— 0.1	6	5,044	s.	30	n.	14	13	14	4	4.4	0.0	0.0
Pueblo	4,685	80	86	25.38	29.99	+ .08	69.8	— 2.3	91	18	82	47	22	57	35	57	51	62	1.89	+ 0.3	11	4,267	e.	33	w.	19	14	12	5	4.4	0.0	0.0
Concordia	1,392	50	58	28.56	30.00	+ .05	72.4	— 4.1	94	8	83	51	14	62	33	63	57	66	5.15	+ 2.3	10	4,374	se.	32	nw.	31	17	7	7	4.3	0.0	0.0
Dodge City	2,509	11	51	27.45	30.01	+ .08	72.4	— 4.1	96	8	84	50	13	60	36	62	57	68	2.43	— 0.2	7	6,165	s.	27	ne.	31	16	10	5	3.7	0.0	0.0
Wichita	1,358	139	158	28.58	29.99	+ .04	74.4	— 3.1	95	7	84	56	14	65	29	65	60	68	4.40	+ 1.3	8	7,044	se.	48	se.	25	12	12	7	4.5	0.0	0.0
Altus	1,410	5					76.8		98	30	87	56	23	66	34				8.47								8	6	17		0.0	0.0
Broken Arrow	765	11	52	29.17	29.98		74.8		94	7	84	57	22	65	27	69	66	80	4.20		9	6,602	s.	38	n.	31	6	12	13	6.3	0.0	0.0
Muskogee	652	4					77.9		97	8	89	58	15	66	34				3.96		8		e				8	10	8		0.0	0.0
Oklahoma	1,214	10	47	28.73	29.98	+ .04	75.6	— 2.9	96	9	85	56	23	66	30	68	65	78	4.86	+ 1.7	12	6,777	s.	37	ne.	9	9	11	11	5.6	0.0	0.0
Southern Slope.							**76.0**	**— 3.1**												**71**	**5.33**	**+ 3.2**								**5.5**		
Abilene	1,738	10	52	28.19	29.96	+ .04	76.6	— 4.6	100	1	85	60	23	68	28	69	67	77	9.03	+ 7.1	14	5,487	s.	25	n.	5	5	10	16	6.8	0.0	0.0
Amarillo	3,676	10	49	26.32	29.98	+ .06	71.6	— 3.0	92	9	83	53	22	60	33	63	59	73	5.52	+ 2.7	11	6,864	s.	34	e.	31	8	21	2	4.9	0.0	0.0
Del Rio	944	64	71	28.96	29.92	+ .02	81.8	— 2.2	100	2	91	68	22	73	25				4.71	+ 2.2	9	6,693	se.	38	ne.	6	9	18	4	5.0	0.0	0.0
Roswell	3,566	75	85	26.38	29.92	+ .04	74.0	— 2.6	98	9	86	52	15	62	37	62	56	63	2.07	+ 0.6	7	4,555	s.	34	w.	11	5	23	3	5.3	0.0	0.0
Southern Plateau.							**78.7**	**— 1.5**												**49**	**1.09**	**0.0**								**2.9**		
El Paso	3,762	110	133	26.20	29.87	+ .03	77.0	— 1.6	98	11	87	60	23	67	29	63	54	54	1.33	— 0.4	8	7,723	e.	42	ne.	5	11	14	6	4.9	0.0	0.0
Santa Fe	7,013	57	66	23.36	29.90	+ .01	65.0	— 2.0	84	7	77	44	28	53	29	53	46	60	1.98	— 0.4	11	4,694	e.	29	nw.	8	9	15	7	4.9	0.0	0.0
Flagstaff	6,908	8	57																													
Phoenix	1,108	76	81	28.68	29.80	+ .09	86.5	— 2.5	108	6	100	64	27	73	38	70	61	49	0.75	— 0.2	9	3,961	e.	33	ne.	13	24	6	1	1.9	0.0	0.0
Yuma	141	9	54	29.66	29.80	+ .04	88.2	— 1.7	112	6	102	60	28	75	36	72	64	51	0.62	+ 0.3	1	4,101	sw.	36	se.	13	27	4	0	1.2	0.0	0.0
Independence	3,957	9	41	25.95	29.90	+ .09	76.6	+ 0.2	102	14	92	47	27	61	37	55	38	31	0.77	+ 0.7	1	3,905	s.	22	s.	24	26	4	1	1.8	0.0	0.0
Middle Plateau.							**71.0**	**— 0.6**												**39**	**0.82**	**+ 0.1**								**2.5**		
Reno	4,532	74	81	25.49	29.89	+ .05	70.2	+ 3.2	102	14	88	45	27	52	44	51	37	39	0.47	+ 0.2	3	4,426	w.	30	w.	8	26	2	3	1.3	0.0	0.0
Tonopah	6,090	12	20	24.14	29.93		72.2		95	14	84	41	27	60	31	51	31	27	0.95	+ 0.6	2	5,961	se.	30	se.	24	19	11	1	2.4	0.0	0.0
Winnemucca	4,344	18	56	25.63	29.94	+ .06	68.6	— 2.2	101	15	88	38	20	50	53	50	35	38	0.76	+ 0.6	4	4,461	ne.	33	s.	24	25	4	2	1.4	0.0	0.0
Modena	5,479	10	43	24.66	29.89	+ .03	69.0	+ 0.4	94	15	85	42	27	53	42	52	40	44	0.81	— 1.0	5	7,353	sw.	58	s.	24	20	8	3	3.1	0.0	0.0
Salt Lake City	4,360	163	203	25.64	29.92	+ .01	73.7	— 1.8	95	17	84	49	27	63	30	57	46	41	1.31	+ 0.5	7	5,456	nw.	44	se.	18	17	11	3	3.3	0.0	0.0
Grand Junction	4,602	60	68	25.42	29.95	+ .05	73.5	— 2.6	95	7	87	48	28	60	36	57	46	45	0.64	— 0.4	5	4,255	se.	32	nw.	20	18	9	4	3.5	0.0	0.0
Northern Plateau.							**70.7**	**+ 0.3**												**45**	**1.35**	**+ 1.0**								**2.9**		
Baker	3,471	48	53	26.47	30.00	+ .05	65.6	+ 0.7	95	15	81	38	30	50	43	52	42	50	1.42	+ 1.0	6	4,325	nw.	19	sw.	29	19	10	2	2.8	0.0	0.0
Boise	2,739	78	86	27.14	29.93	.00	72.2	+ 0.4	107	15	88	42	30	57	43	56	44	41	0.33	+ 0.2	4	3,451	w.	24	se.	25	25	4	2	1.5	0.0	0.0
Lewiston	757	40	48	29.16	29.96	+ .01	73.8	+ 0.3	106	14	90	45	31	58	44				0.72	+ 0.4	5	2,365	e.	28	w.	17	21	4	0	3.2	0.0	0.0
Pocatello	4,477	60	68	25.51	29.93	+ .01	69.0	— 1.5	96	16	83	40	31	55	38	52	40	42	2.53	+ 2.0	8	5,986	se.	36	sw.	28	16	12	3	3.7	0.0	0.0
Spokane	1,929	101	110	27.96	29.96	+ .01	69.8	+ 1.9	99	14	84	42	31	56	39	55	44	48	1.25	+ 0.8	4	4,069	sw.	25	sw.	27	15	12	4	3.5	0.0	0.0
Walla Walla	991	57	65	28.90	29.96	.00	73.8	0.0	103	14	86	47	26	61	36	58	45	42	1.87	+ 1.4	4	3,121	s.	24	w.	29	22	5	4	2.5	0.0	0.0
North Pacific Coast Region.							**63.2**	**+ 1.4**												**73**	**1.44**	**+ 0.7**								**3.6**		
North Head	211	11	56	29.84	30.07	+ .04	56.2	— 1.7	76	31	60	49	12	52	21	54	53	91	1.46	+ 0.9	8	11,499	nw.	74	se.	27	11	15	5	4.2	0.0	0.0
Port Angeles	29	8	53	30.05	30.08		58.4		83	12	68	41	18	48	32				1.03	+ 0.4	4	4,516	nw.	41	w.	16	17	9	5	3.7	0.0	0.0
Seattle	125	215	250	29.92	30.05	+ .05	64.4	+ 1.3	86	13	74	50	30	55	27	57	52	69	1.15	+ 0.7	4	4,963	n.	42	s.	27	21	3	7	3.3	0.0	0.0
Tacoma	213	113	120	29.82	30.04	+ .02	64.6	+ 1.6	85	14	75	47	18	54	28	57	52	68	1.26	+ 0.6	3	3,923	n.	28	sw.	16	11	11	9	5.2	0.0	0.0
Tatoosh Island	86	7	57	29.96	30.06	+ .06	55.0	— 0.3	68	8	59	47	19	51	16	53	52	93	3.74	+ 1.6	8	8,942	s.	37	e.	29	17	5	9	3.6	0.0	0.0
Yakima	1,071	4																														
Medford	1,425	4																														
Portland, Oreg	153	68	106	29.87	30.02	+ .01	69.3	+ 3.8	98	12	81	44	30	58	31	60	53	60	1.25	+ 0.6	4	4,894	nw.	23	ne.	31	18	7	6	3.3	0.0	0.0
Roseburg	510	9	57	29.47	30.01	+ .01	70.0	+ 3.8	101	12	86	43	30	54	44	58	49	56	0.22	— 0.1	3	2,751	n.	18	nw.	17	23	7	1	1.9	0.0	0.0
Middle Pacific Coast Region.							**66.7**	**+ 1.9**												**62**	**0.13**	**+ 0.1**								**2.7**		
Eureka	62	73	89	29.94	30.02	+ .02	56.1	+ 0.3	68	27	61	47	27	52	21	53	51	87	0.49	+ 0.4	2	3,972	sw.	30	n.	18	9	13	9	5.5	0.0	0.0
Mount Tamalpais	2,375	11	18	27.51	29.94	+ .01	69.6	+ 3.7	96	13	77	46	22	62	27	55	43	47	0.00	0.0	0	11,695	nw.	64	nw.	27	23	5	3	0.2	0.0	0.0
Point Reyes Light	490	7	18	29.40	29.92		54.8	+ 0.3	64	20	59	47	2	51	11				0.06		2	12,566	nw.	58	nw.	23	3	5	23	8.1	0.0	0.0
Red Bluff	332	50	56	29.50	29.84	— .02	82.0	+ 1.0	110	14	98	54	26	66	39	61	45	35	0.31	+ 0.3	1	3,363	se.	21	nw.	18	29	1	1	1.1	0.0	0.0
Sacramento	69	106	117	29.79	29.86	+ .01	76.0	+ 3.9	108	15	93	53	27	59	43	61	51	50	T.	0.0	0	5,808	s.	28	s.	24	28	2	1	0.7	0.0	0.0
San Francisco	155	208	243	29.76	29.93	+ .01	60.1	+ 2.1	79	30	67	50	11	53	24	56	55	89	0.00	0.0	0	9,694	sw.	40	w.	6	22	8	1	1.6	0.0	0.0
San Jose	141	12	110	29.80	30.00		68.7	+ 2.0	93	15	83	49	23	54	39				0.00	0.0	0	4,501	nw.	24	sw.	19	27	4	0	1.8	0.0	0.0
South Pacific Coast Region.							**72.5**	**+ 1.2**												**64**	**0.05**	**0.0**								**2.2**		
Fresno	327	89	98	29.50	29.84	+ .02	81.5	+ 0.3	110	16	97	56	27	66	37	61	44	34	0.15	+ 0.2	1	5,751	nw.	21	nw.	7	28	3	0	0.5	0.0	0.0
Los Angeles	338	159	191	29.57	29.92	+ .04	72.4	+ 0.9	92	15	82	57	27	63	27	63	59	72	0.00	0.0	0	3,951	sw.	18	w.	21	20	9	2	2.6	0.0	0.0
San Diego	87	62	70	29.82	29.91	+ .02	70.4	+ 1.7	82	16	75	59	28	66	14	65	62	79	0.01	0.0	1	4,624	nw.	19	nw.	5	21	7	3	2.9	0.0	0.0
San Luis Obispo	201	32	40	29.74	29.95	+ .01	65.6	+ 2.1	92	15	78	48	10	53	39	56	52	72	0.03	0.0	1	2,631	nw.	17	nw.	27	21	8	2	2.7	0.0	0.0
West Indies.																																
San Juan, P. R	82	8	54	29.93	30.01		79.8		90	30	84	71	24	76	16				5.38	— 2.0	19	10,450	e.	36	n.	22	10	18	3	4.8	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.72	29.85	+ .01	80.3	+ 0.1	92	25	86	70	15	74	17	75	74	86	12.22	+ 4.3	19	4,945	nw.	30	nw.	20	0	14	17	7.7	0.0	0.0
Colon	36	7	97	29.82	29.86	.00	80.7	— 0.9	90	14	86	73	22	76	15	76	75	86	23.04	+ 8.0	28	6,519	w.	30	n.	16	0	6	25	8.0	0.0	0.0
Alaska.																																
Juneau	80	11	49																													

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during August, 1920, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	11–12	9:15 p. m.	D. N. a. m.	0.84	9:28 p. m.	9:53 p. m.	0.01	0.12	0.25	0.40	0.50	0.56									
	16	10:00 a. m.	3:45 p. m.	2.74	12:15 p. m.	1:01 p. m.	0.26	0.10	0.17	0.29	0.41	0.51	0.57	0.65	0.77	0.87	0.91				
					2:39 p. m.	3:22 p. m.	1.56	0.07	0.12	0.25	0.52	0.73	0.95	1.00	1.08	1.17					
Albany, N. Y.	15	12:45 a. m.	D. N. a. m.	0.52	12:57 a. m.	1:12 a. m.	0.01	0.14	0.37	0.50											
Alpena, Mich.	21			0.89														0.25			
Amarillo, Tex.	4–5	5:25 p. m.	D. N. a. m.	1.50	10:52 p. m.	11:12 p. m.	0.18	0.16	0.54	0.86	1.04										
Anniston, Ala.	8	4:24 p. m.	5:20 p. m.	0.60	4:30 p. m.	4:42 p. m.	0.01	0.26	0.50	0.54											
	17	2:35 p. m.	9:30 p. m.	0.88	2:50 p. m.	3:06 p. m.	0.01	0.14	0.32	0.46	0.51										
Asheville, N. C.	9			1.11														0.64			
Atlanta, Ga.	9	1:55 p. m.	2:30 p. m.	1.08	2:05 p. m.	2:30 p. m.	0.01	0.22	0.35	0.66	0.90	1.07									
	9	2:55 p. m.	3:25 p. m.	0.64	3:00 p. m.	3:20 p. m.	0.01	0.21	0.34	0.50	0.62										
	11	6:30 a. m.	10:32 a. m.	0.90	10:02 a. m.	10:17 a. m.	0.29	0.16	0.47	0.56											
	12	1:19 p. m.	1:58 p. m.	0.88	1:23 p. m.	1:56 p. m.	0.01	0.34	0.43	0.43	0.48	0.60	*0.76	0.87							
	15	2:53 p. m.	9:45 p. m.	2.07	2:53 p. m.	3:21 p. m.	0.00	0.48	0.98	1.20	1.45	1.69	1.76								
	29	10:10 a. m.	11:05 a. m.	0.73	10:35 a. m.	10:53 a. m.	0.06	0.27	0.52	0.61	0.65										
Atlantic City, N. J.	5–6	3:38 p. m.	6:10 a. m.	1.36	12:52 a. m.	1:20 a. m.	0.27	0.14	0.29	0.42	0.56	0.75	0.91								
Augusta, Ga.	27	3:20 p. m.	5:15 p. m.	2.00	3:29 p. m.	4:12 p. m.	0.02	0.08	0.27	0.60	0.97	1.26	1.48	1.67	1.86	1.94					
Baker, Oreg.	25			1.09														0.21			
Baltimore, Md.	1				1:00 p. m.	1:21 p. m.	0.03	0.18	0.30	0.47	0.54	0.56									
		11:40 a. m.	1:50 p. m.	0.95	2:22 p. m.	2:44 p. m.	0.07	0.11	0.31	0.63	0.79	0.87									
		2:10 p. m.	6:50 p. m.	2.05	4:20 p. m.	4:44 p. m.	1.16	0.19	0.30	0.43	0.63	0.82									
	17	2:10 p. m.	3:45 p. m.	0.97	2:20 p. m.	2:56 p. m.	0.01	0.08	0.38	0.57	0.60	0.72	0.79	0.87	0.89						
Bentonville, Ark.	26	2:20 p. m.	4:50 p. m.	0.75	2:31 p. m.	2:50 p. m.	0.06	0.12	0.33	0.47	0.67										
	30	4:40 a. m.	8:30 a. m.	1.65	4:55 a. m.	5:28 a. m.	0.03	0.06	0.18	0.55	0.89	1.18	1.28	1.36							
Binghamton, N. Y.	7	2:50 p. m.	5:30 p. m.	1.31	3:07 p. m.	3:32 p. m.	0.01	0.13	0.39	0.76	0.96	1.01									
Birmingham, Ala.	10	D. N. a. m.	6:57 a. m.	1.19	5:22 a. m.	6:00 a. m.	0.04	0.26	0.48	0.62	0.71	0.78	0.91	1.07	1.12						
	15	12:37 p. m.	1:31 p. m.	0.63	12:39 p. m.	12:58 p. m.	0.01	0.12	0.30	0.52	0.62										
	16	12:40 p. m.	2:31 p. m.	0.95	12:40 p. m.	12:55 p. m.	0.00	0.29	0.71	0.94											
	20	3:08 p. m.	5:39 p. m.	2.97	3:14 p. m.	5:04 p. m.	0.01	0.17	0.31	0.53	0.53	0.53	0.54	0.54	0.72	1.00	1.21	1.25	1.59	2.66	2.96
Bismarck, N. Dak.	28			0.24														0.10			
Block Island, R. I.	31	3:40 p. m.	4:28 p. m.	0.94	3:43 p. m.	4:07 p. m.	0.01	0.20	0.40	0.59	0.85	0.91									
Boise, Idaho.	25			0.20														0.16			
Boston, Mass.	7			1.00														0.64			
Buffalo, N. Y.	21			0.87														0.40			
Burlington, Vt.	22			1.26														0.54			
Cairo, Ill.	14	11:17 a. m.	9:00 p. m.	1.14	11:21 a. m.	11:36 a. m.	0.01	0.24	0.50	0.71											
Canton, N. Y.	9–10			0.31														0.25			
Charles City, Iowa.	20	2:45 a. m.	5:20 a. m.	0.96	2:49 a. m.	3:41 a. m.	0.01	0.10	0.19	0.21	0.28	0.36	0.44	0.48	0.55	0.65	0.72	0.79			
Charleston, S. C.	27	1:25 p. m.	4:10 p. m.	1.09	2:40 p. m.	3:05 p. m.	0.04	0.30	0.43	0.47	0.49	0.60									
Charlotte, N. C.	8	4:10 p. m.	5:50 p. m.	0.81	4:13 p. m.	4:25 p. m.	0.01	0.41	0.61	0.66											
	9	9:12 a. m.	12:50 p. m.	1.00	10:55 a. m.	11:15 a. m.	0.27	0.12	0.36	0.58	0.63										
	14	2:12 p. m.	3:55 p. m.	1.09	2:14 p. m.	2:46 p. m.	0.01	0.19	0.46	0.62	0.86	0.94	0.98	1.04							
	19	2:02 p. m.	5:20 p. m.	0.73	2:04 p. m.	2:24 p. m.	0.01	0.28	0.44	0.57	0.63										
Chattanooga, Tenn.	10	2:10 a. m.	5:35 a. m.	1.32	2:17 a. m.	3:07 a. m.	0.02	0.11	0.27	0.33	0.42	0.53	0.66	0.74	0.84	0.97	1.04				
	13	5:02 a. m.	11:38 a. m.	2.41	6:42 a. m.	7:56 a. m.	0.27	0.06	0.14	0.22	0.29	0.40	0.56	0.64	0.68	0.71	0.78	0.91	1.11		
	14–15	7:50 p. m.	4:25 a. m.	0.89	9:30 p. m.	9:45 p. m.	0.02	0.25	0.45	0.51											
Cheyenne, Wyo.	8			0.33														0.33			
Chicago, Ill.	20–21			1.25														0.60			
Cincinnati, Ohio.	7	3:16 p. m.	6:05 p. m.	2.70	3:16 p. m.	3:48 p. m.	0.00	0.38	1.16	1.78	2.13	2.47	2.57	2.60							
Cleveland, Ohio.	27			1.53														0.72			
Columbia, Mo.	20			1.36														0.67			
Columbia, S. C.	13	7:30 p. m.	9:30 p. m.	0.66	7:51 p. m.	8:16 p. m.	0.03	0.06	0.19	0.42	0.50	0.56									
Columbus, Ohio.	14	12:30 p. m.	1:45 p. m.	1.07	12:45 p. m.	1:05 p. m.	0.01	0.25	0.59	0.75	0.84										
Concord, N. H.	22	7:18 p. m.	7:54 p. m.	1.02	7:18 p. m.	7:51 p. m.	0.00	0.27	0.42	0.60	0.82	0.90	0.97	1.01							
Concordia, Kans.	11	4:18 p. m.	8:34 p. m.	1.71	4:22 p. m.	4:40 p. m.	0.01	0.42	0.84	1.27	1.35										
Corpus Christi, Tex.	7			0.65														(*)			
Dallas, Tex.	2	1:40 a. m.	3:30 a. m.	0.71	2:51 a. m.	3:16 a. m.	0.15	0.11	0.17	0.32	0.48	0.54									
	5	2:44 p. m.	5:52 p. m.	1.03	5:05 p. m.	5:38 p. m.	0.01	0.27	0.62	0.74	0.85	0.91	0.96	1.00							
	24	4:57 p. m.	6:52 p. m.	1.57	5:19 p. m.	6:23 p. m.	0.02	0.13	0.29	0.62	0.77	0.93	1.07	1.17	1.26	1.31	1.34	1.48	1.53		
	27	11:09 a. m.	7:40 p. m.	1.27	3:56 p. m.	4:31 p. m.	0.52	0.07	0.14	0.19	0.34	0.47	0.51	0.57							
Davenport, Iowa.	20	5:02 p. m.	5:48 p. m.	1.01	5:03 p. m.	5:24 p. m.	0.01	0.06	0.37	0.72	0.90	0.94									
Dayton, Ohio.	21			1.17														0.69			
Del Rio, Tex.	12–13	D. N. p. m.	D. N. a. m.	1.09	12:01 a. m.	12:28 a. m.	0.06	0.09	0.24	0.33	0.41	0.48	0.52								
Denver, Colo.	20			0.66														0.22			
Des Moines, Iowa.	6			0.68														0.33			
Detroit, Mich.	9–10	9:04 p. m.	D. N. a. m.	0.82	9:06 p. m.	9:22 p. m.	0.01	0.16	0.36	0.47	0.50										
	16	5:20 p. m.	D. N. p. m.	1.33	7:37 p. m.	7:55 p. m.	0.35	0.10	0.28	0.45	0.51										
Devils Lake, N. Dak.	19			1.16														0.49			
Dodge City, Kans.	19–20	10:10 p. m.	D. N. a. m.	1.00	1:11 a. m.	1:36 a. m.	0.31	0.05	0.19	0.37	0.51	0.62									
Drexel, Nebr.	20	7:50 a. m.	1:30 p. m.	1.66	8:57 a. m.	9:40 a. m.	0.07	0.07	0.10	0.18	0.24	0.27	0.51	0.66	0.89	0.94					
Dubuque, Iowa.	20–21	9:15 p. m.	D. N. a. m.	1.37	10:40 p. m.	11:15 p. m.	0.24	0.10	0.29	0.48	0.52	0.63	0.76	0.83							
Duluth, Minn.	29			0.69														0.40			
Eastport, Me.	11			1.39														0.35			
Elkins, W. Va.	6–7			0.90														0.31			
Ellendale, N. Dak.	5			0.23														0.23			
El Paso, Tex.	17			0.69														0.45			
Erie, Pa.	16	3:18 p. m.	4:55 p. m.	1.41	3:50 p. m.	4:35 p. m.	0.01	0.10	0.20	0.38	0.54	0.66	0.90	1.08	1.27	1.35					
Escanaba, Mich.	29			1.00														0.65			
Eureka, Cal.	27			0.44														0.23			
Evansville, Ind.	6	2:33 p. m.	4:35 p. m.	1.11	2:36 p. m.	2:58 p. m.	0.01	0.31	0.53	0.75	0.89	0.94									
	7	12:43 p. m.	2:05 p. m.	0.95	12:49 p. m.	1:14 p. m.	0.01	0.09	0.32	0.37	0.62	0.82									
	12–13	11:15 p. m.	12:30 a. m.	0.97	11:34 p. m.	11:48 p. m.	0.05	0.28	0.72	0.91											
	15	2:45 a. m.	11:49 a. m.	2.16	6:59 a. m.	8:08 a. m.	0.10	0.07	0.21	0.39	0.53	0.63	0.70	0.75	0.91	1.02	1.13	1.36	1.66		
Flagstaff, Ariz.																					
Fort Smith, Ark.	29			0.34														0.29			
Fort Wayne, Ind.	7	3:05 p. m.	4:10 p. m.	0.66	3:11 p. m.	3:23 p. m.	0.01	0.26	0.57	0.64											
Fort Worth, Tex.	9–10	10:53 p. m.	7:15 a. m.	0.97	10:55 p. m.	11:15 p. m.	0.01	0.10	0.41	0.65	0.73										
Fresno, Cal.	24			0.15														0.10			
Galveston, Tex.	19			0.74														0.64			
Grand Haven, Mich.	21			0.53														0.36			
Grand Junction, Colo.	3			0.45														0.21			
Grand Rapids, Mich.	21			0.55														0.32			
Green Bay, Wis.	12			0.45														0.29			
Greenville, S. C.	12			0.47														0.36			
Hannibal, Mo.	20	3:20 p. m.	4:18 p. m.	0.75	3:40 p. m.	4:02 p. m.	0.03	0.29	0.38	0.52	0.64	0.69									
Harrisburg, Pa.	18	8:45 p. m.	D. N. p. m.	2.43	9:16 p. m.	10:05 p. m.	0.03	0.31	0.73	1.06	1.27	1.41	1.61	1.86	2.13	2.32	2.37				
Hartford, Conn.	16	3:05 p. m.	4:40 p. m.	1.47	3:05 p. m.	3:51 p. m.	0.00	0.13	0.26	0.29	0.37	0.38	0.53	0.76	1.16	1.36	1.38				
Hatteras, N. C.	2	4:18 p. m.	D. N. p. m.	1.78	7:41 p. m.	8:09 p. m.	0.41	0.09	0.12	0.25	0.52	0.72	0.76								
Havre, Mont.	2–3			0.29														0.27			
Helena, Mont.	9			0.35														0.23			
Houghton, Mich.	11			0.41														0.25			

*Self-register not in use.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during August, 1920, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated. 5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Houghton, Mich	11			0.41																	
Houston, Tex	5	3:40 p. m.	4:45 p. m.	0.95	3:40 p. m.	4:19 p. m.	0.00	0.09	0.17	0.30	0.46	0.62	0.76	0.85	0.91			0.25			
	8	11:21 a. m.	12:28 p. m.	1.66	11:26 a. m.	12:06 p. m.	0.01	0.22	0.51	0.77	0.99	1.19	1.41	1.51	1.61						
	16	4:27 p. m.	5:40 p. m	1.20	4:30 p. m.	4:57 p. m.	0.01	0.23	0.52	0.73	0.93	1.05	1.09								
	20	2:55 p. m.	5:15 p. m.	1.80	3:06 p. m.	4:26 p. m.	0.01	0.27	0.48	0.61	0.72	0.75	0.85	0.97	1.13	1.25	1.43	1.49	1.74		
	23	3:55 p. m.	5:30 p. m.	1.30	4:06 p. m.	4:55 p. m.	0.01	0.12	0.23	0.28	0.41	0.73	0.94	1.09	1.16	1.21	1.25				
	24	3:05 p. m.	9:45 p. m.	2.48	3:55 p. m.	5:41 p. m.	0.04	0.09	0.19	0.25	0.36	0.53	0.68	0.81	0.90	0.98	1.05	1.18	1.41	1.79	1.95
Huron, S. Dak	28	3:20 p. m.	6:00 p. m.	0.86	3:52 p. m.	4:17 p. m.	0.03	0.17	0.30	0.42	0.52	0.66									
Independence, Calif	24			0.77																	
Indianapolis, Ind	7			0.69																	
Iola, Kans	12	12:15 a. m.	D.N. a. m.	1.34	12:20 a. m.	1:00 a. m.	0.01	0.05	0.25	0.34	0.43	0.54	0.73	0.95	1.02			0.33			
	31	4:35 p. m.	5:20 p. m.	0.74	4:36 p. m.	5:00 p. m.	0.01	0.14	0.38	0.53	0.62	0.69						0.43			
Jacksonville, Fla	30	1:15 p. m.	2:41 p. m.	2.72	1:18 p. m.	2:06 p. m.	0.01	0.13	0.52	0.97	1.46	1.73	2.03	2.24	2.39	2.52	2.57				
Kalispell, Mont	10	5:40 p. m.	9:30 p. m.	1.06	5:50 p. m.	6:08 p. m.	0.01	0.18	0.62	0.88	0.95										
Kansas City, Mo	19	4:10 a. m.	7:00 a. m.	1.80	6:12 a. m.	6:48 a. m.	0.38	0.14	0.25	0.36	0.52	0.78	1.10	1.39	1.42						
Keokuk, Iowa	31			0.50																	
Key West, Fla	5–6	8:15 p. m.	D.N. a. m.	0.90	8:18 p. m.	8:46 p. m.	0.01	0.26	0.35	0.43	0.45	0.68	0.78					0.26			
	15	7:27 p. m.	10:20 p. m.	2.27	7:35 p. m.	8:17 p. m.	0.01	0.14	0.27	0.37	0.53	1.02	1.51	1.90	2.11	2.16					
	27	9:30 a. m.	11:05 a. m.	0.71	9:55 a. m.	10:13 a. m.	0.06	0.18	0.30	0.56	0.64										
Knoxville, Tenn	8	3:50 p. m.	4:50 p. m.	0.58	4:03 p. m.	4:21 p. m.	0.03	0.09	0.20	0.44	0.53										
	9–10	D.N. p. m.	7:55 a. m.	1.71	1:14 a. m.	1:47 a. m.	0.06	0.16	0.20	0.21	0.32	0.54	0.60	0.65							
	27	D.N. a. m.	D.N. a. m.	1.53	2:54 a. m.	3:09 a. m.	0.13	0.05	0.37	0.60											
La Crosse, Wis	29			0.48																	
Lander, Wyo	11			0.18																	
Lansing, Mich	6			0.62														0.36			
Lewiston, Idaho	29			0.38														0.10			
Lexington, Ky	7	1:04 p. m.	8:45 p. m.	1.36	4:06 p. m.	4:26 p. m.	0.26	0.10	0.50	0.64	0.69							0.43			
	19	2:58 p. m.	3:47 p. m.	0.62	3:06 p. m.	3:22 p. m.	0.01	0.18	0.42	0.56	0.60							0.16			
	27	8:50 p. m.	9:25 p. m.	0.75	8:56 p. m.	9:20 p. m.	0.01	0.10	0.15	0.39	0.64	0.73									
Lincoln, Nebr	20	10:29 a. m.	12:40 p. m.	0.90	10:35 a. m.	11:05 a. m.	0.01	0.10	0.22	0.37	0.52	0.56	0.62								
Little Rock, Ark	9	3:10 p. m.	4:45 p. m.	0.67	3:36 p. m.	3:56 p. m.	0.05	0.13	0.33	0.49	0.60										
Los Angeles, Calif	(‡)			(‡)																	
Louisville, Ky	6–7	10:05 p. m.	D.N. a. m.	0.88	12:50 a. m.	1:24 a. m.	0.10	0.07	0.17	0.29	0.36	0.49	0.57	0.61				(‡)			
	7	4:12 p. m.	8:47 p. m.	1.39	4:14 p. m.	4:33 p. m.	T.	0.26	0.45	0.56	0.62										
	30	12:10 p. m.	12:44 p. m.	0.74	12:13 p. m.	12:38 p. m.	T.	0.08	0.17	0.44	0.60	0.73									
Ludington, Mich	29			0.70																	
Lynchburg, Va	18	3:40 p. m.	6:10 p. m.	1.04	4:23 p. m.	5:00 p. m.	0.02	0.32	0.47	0.56	0.66	0.72	0.78	0.84				0.60			
	19	6:15 a. m.	8:30 a. m.	1.66	6:49 a. m.	7:34 a. m.	0.03	0.13	0.27	0.40	0.55	0.68	0.89	1.14	1.35	1.47					
Macon, Ga	2	5:26 p. m.	9:10 p. m.	0.93	5:52 p. m.	6:31 p. m.	0.14	0.08	0.17	0.25	0.33	0.38	0.49	0.61	0.70						
	6	12:05 p. m.	1:30 p. m.	0.94	12:16 p. m.	12:44 p. m.	0.01	0.18	0.41	0.66	0.79	0.85	0.89								
Madison, Wis	20			1.11																	
Marquette, Mich	4	8:13 p. m.	11:45 p. m.	1.12	8:20 p. m.	9:05 p. m.	0.01	0.06	0.10	0.22	0.33	0.53	0.67	0.73	0.87	0.95		0.49			
Memphis, Tenn	12	6:38 p. m.	D.N. p. m.	1.09	8:56 p. m.	9:28 p. m.	0.13	0.12	0.23	0.27	0.45	0.59	0.76	0.83							
Meridian, Miss	8	2:50 p. m.	4:30 p. m.	1.59	2:50 p. m.	3:40 p. m.	0.00	0.21	0.22	0.22	0.36	0.69	0.96	1.15	1.31	1.47	1.55				
	14	4:10 p. m.	5:30 p. m.	0.56	4:12 p. m.	4:35 p. m.	0.01	0.16	0.26	0.27	0.44	0.52									
	26	1:23 p. m.	4:10 p. m.	1.15	1:53 p. m.	2:15 p. m.	0.01	0.22	0.40	0.61	0.77	0.80									
Miami, Fla	15			0.85																	
Milwaukee, Wis	12			0.55																	
Minneapolis, Minn	29			0.78														0.67			
Mobile, Ala	17	2:35 p. m.	5:45 p. m.	0.86	2:51 p. m.	3:41 p. m.	0.01	0.12	0.16	0.24	0.35	0.38	0.39	0.46	0.56	.62	0.71	0.42			
	27	5:55 a. m.	8:05 a. m.	0.67	6:04 a. m.	6:35 a. m.	0.01	0.19	0.33	0.39	0.45	0.54	0.64	0.65				0.53			
Modena, Utah	24			0.25																	
Montgomery, Ala	3	8:00 p. m.	9:30 p. m.	0.66	8:13 p. m.	8:40 p. m.	0.04	0.11	0.24	0.34	0.47	0.57	0.60					0.23			
	11	5:10 p. m.	D. N. p. m.	0.86	5:26 p. m.	5:45 p. m.	0.04	0.34	0.51	0.65	0.78										
	19	1:05 p. m.	3:45 p. m.	1.04	1:07 p. m.	1:25 p. m.	0.01	0.36	0.64	0.88	0.95										
	22	6:12 p. m.	D.N.p. m.	0.70	6:12 p. m.	6:22 p. m.	0.00	0.27	0.52												
Moorhead, Minn	19			0.66																	
Mount Tamalpais, Calif	(‡)			(‡)																	
Nantucket, Mass	15–16	10:50 p. m.	4:20 a. m.	0.96	1:35 a. m.	2:06 a. m.	0.39	0.11	0.14	0.17	0.36	0.45	0.56	0.57				0.48			
Nashville, Tenn	7–8	10:20 p. m.	3:20 a. m.	1.66	10:32 p. m.	11:10 p. m.	0.03	0.08	0.26	0.45	0.71	0.96	1.14	1.23	1.30			(‡)			
	9	4:53 p. m.	5:55 p. m.	0.84	5:14 p. m.	5:39 p. m.	0.01	0.14	0.25	0.49	0.66	0.76									
	10	3:45 a. m.	7:30 a. m.	1.71	6:05 a. m.	6:40 a. m.	0.82	0.10	0.28	0.47	0.57	0.70	0.81	0.86							
New Haven, Conn	10–11	10:40 p. m.	10:30 a. m.	0.95	2:56 a. m.	3:23 a. m.	0.04	0.20	0.22	0.27	0.29	0.49	0.56								
New Orleans, La	11	10:24 a. m.	11:50 a. m.	0.58	10:27 a. m.	10:42 a. m.	0.01	0.12	0.36	0.52											
New York, N. Y	16	5:24 p. m.	6:35 p. m.	1.15	5:31 p. m.	6:01 p. m.	T.	0.07	0.35	0.63	0.82	0.93	1.02								
Norfolk, Va	10			0.69																	
Northfield, Vt	11			0.52																	
North Head, Wash	28			0.73														0.51			
North Platte, Nebr	19–20	10:37 p. m.	11:57 a. m.	3.19	11:02 p. m.	12:18 a. m.	0.02	0.17	0.44	0.56	0.64	0.90	1.17	1.52	1.69	1.74	1.78	0.28			
Oklahoma, Okla	11	3:38 p. m.	4:45 p. m.	0.93	3:52 p. m.	4:12 p. m.	0.02	0.09	0.48	0.70	0.84							0.26			
	20–21	7:40 p. m.	7:05 a. m.	0.97	7:48 p. m.	8:03 p. m.	0.04	0.10	0.28	0.35	0.37	0.43	0.50					1.88	2.27		
	27	12:02 p. m.	1:40 p. m.	0.76	12:57 p. m.	1:34 p. m.	0.04	0.14	0.26	0.33	0.41	0.54	0.67	0.72							
Omaha, Nebr	20			0.78																	
Oswego, N. Y	9	2:51 p. m.	5:30 p. m.	0.56	3:08 p. m.	3:28 p. m.	0.01	0.15	0.19	0.43	0.51							0.54			
Palestine, Tex	8	6:35 p. m.	7:50 p. m.	1.41	6:40 p. m.	7:20 p. m.	0.01	0.07	0.23	0.41	0.76	0.99	1.16	1.27	1.33						
	12	2:42 p. m.	3:45 p. m.	0.70	2:57 p. m.	3:17 p. m.	0.01	0.05	0.32	0.51	0.63										
	24	1:08 p. m.	3:05 p. m.	1.66	1:16 p. m.	1:56 p. m.	0.01	0.22	0.50	0.78	1.00	1.36	1.48	1.54							
Parkersburg, W. Va	26	2:57 p. m.	5:10 p. m.	0.91	2:59 p. m.	3:27 p. m.	0.01	0.16	0.22	0.28	0.39	0.70									
	19	5:57 p. m.	8:15 p. m.	1.05	6:05 p. m.	6:23 p. m.	0.01	0.18	0.53	0.83	0.91										
Pensacola, Fla	7	5:21 a. m.	1:50 p. m.	2.20	10:59 a. m.	11:13 a. m.	1.58	0.19	0.44	0.52											
	8	5:55 a. m.	7:25 a. m.	1.17	6:50 a. m.	7:21 a. m.	0.25	0.20	0.37	0.54	0.67	0.76	0.82	0.92							
	8	7:50 a. m.	10:36 a. m.	1.63	8:40 a. m.	9:21 a. m.	0.11	0.19	0.39	0.56	0.77	0.85	0.89	0.96	1.05	1.08					
Peoria, Ill	26–27	9:30 p. m.	1:45 a. m.	0.99	10:28 p. m.	10:49 p. m.	0.10	0.07	0.12	0.38	0.65	0.68									
	20	10:35 a. m.	11:15 a. m.	0.87	10:35 a. m.	11:02 a. m.	0.00	0.30	0.41	0.68	0.71	0.84	0.87								
Philadelphia, Pa	10–11	5:15 p. m.	D. N. a. m.	2.11	7:41 p. m.	8:07 p. m.	0.41	0.10	0.13	0.24	0.46	0.72	0.77								
	11	9:55 p. m.	10:40 p. m.	0.58	10:03 p. m.	10:13 p. m.	0.01	0.18	0.53												
	14	7:28 p. m.	8:05 p. m.	0.83	7:35 p. m.	7:54 p. m.	0.02	0.08	0.25	0.63	0.81										
	18	6:25 p. m.	8:35 p. m.	1.20	6:28 p. m.	6:53 p. m.	0.01	0.27	0.58	0.84	1.07	1.15									
Phoenix, Ariz	1			0.19																	
Pierre, S. Dak	10			0.41														0.19			
Pittsburgh, Pa	30			0.66														0.38			
Pocatello, Idaho	2	1:08 p. m.	3:38 p. m.	1.27	2:43 p. m.	3:31 p. m.	0.06	0.10	0.26	0.49	0.62	0.77	0.94	1.05	1.09	1.16	1.20	0.45			
Point Reyes Light, Calif	25			0.04																	
Port Angeles, Wash	27			0.37																	
Port Huron, Mich	9	6:38 p. m.	8:15 p. m.	1.15	7:01 p. m.	7:30 p. m.	0.01	0.21	0.47	0.74	0.96	1.03	1.09					0.01			
	10	1:39 p. m.	3:25 p. m.	1.55	1:45 p. m.	2:23 p. m.	0.03	0.05	0.18	0.46	0.82	1.06	1.32	1.42	1.47			0.18			
	21	3:00 p. m.	7:10 p. m.	1.31	3:03 p. m.	3:29 p. m.	0.01	0.08	0.10	0.14	0.35	0.81	0.82								
Portland, Me	14	4:25 p. m.	8:14 p. m.	2.30	4:43 p. m.	5:18 p. m.	0.03	0.30	0.55	0.70	0.75	0.86	0.98	1.13							
					60:3 p. m.	6:45 p. m.	1.24	0.09	0.17	0.39	0.50	0.57	0.64	0.77	0.91	0.97					

‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during August, 1920, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Portland, Oreg.	28			0.67														0.30			
Providence, R. I.	15	3:30 a. m.	6:15 a. m.	1.32	3:57 a. m.	4:19 a. m.	0.06	0.22	0.57	0.73	0.80	0.84									
Pueblo, Colo.	20	3:22 p. m.	6:03 p. m.	1.19	3:48 p. m.	4:24 p. m.	0.05	0.05	0.14	0.19	0.36	0.71	0.91	0.97	1.01						
Raleigh, N. C.	8	2:39 p. m.	4:15 p. m.	0.60	2:41 p. m.	3:04 p. m.	0.01	0.12	0.29	0.39	0.45	0.50									
	9	1:08 p. m.	1:50 p. m.	0.60	1:20 p. m.	1:34 p. m.	0.04	0.34	0.49	0.55											
Rapid City, S. Dak.	10			0.55														0.47			
Reading, Pa.	16	9:25 a. m.	11:05 a. m.	1.46	9:43 a. m.	10:45 a. m.	0.03	0.17	0.37	0.48	0.53	0.58	0.63	0.72	0.82	1.02	1.16	1.38	1.43		
Red Bluff, Calif.	25			0.31														0.22			
Reno, Nev.	25			0.25														0.09			
Richmond, Va.	6	6:40 p. m.	D.N. p. m.	0.97	6:59 p. m.	7:30 p. m.	0.02	0.10	0.30	0.36	0.47	0.57	0.74	0.76							
	17	7:40 p. m.	D.N. p. m.	1.02	8:11 p. m.	8:53 p. m.	0.13	0.11	0.18	0.26	0.30	0.40	0.44	0.61	0.66	0.68					
	27–28	11:35 a. m.	7:25 p. m.	2.94	12:39 p. m.	1:02 p. m.	0.10	0.10	0.26	0.53	0.64	0.71									
					11:37 a. m.	12:31 p. m.	1.76	0.05	0.10	0.15	0.20	0.28	0.38	0.48	0.55	0.61	0.72	0.75			
Rochester, N. Y.	9			0.58														0.46			
Roseburg, Oreg.	27			0.20														0.08			
Roswell, N. Mex.	16			1.58														0.47			
Sacramento, Cal.	24			T.														T.			
Saginaw, Mich.	9			0.94														0.47			
St. Joseph, Mo.	28			0.62														0.27			
St. Louis, Mo.	15	D.N. a.m.	6:20 a. m.	0.99	2:30 a. m.	2:45 a. m.	0.03	0.24	0.64	0.81											
St. Paul, Minn.	29			0.51														0.29			
Salt Lake City, Utah	27			0.67														0.26			
San Antonio, Tex.	13	3:38 a. m.	6:20 a. m.	1.02	4:24 a. m.	4:49 a. m.	0.36	0.06	0.17	0.33	0.42	0.50									
San Diego, Calif.	18			0.01														0.01			
Sand Key, Fla.	2			0.46														0.46			
Sandusky, Ohio	13			0.50														0.50			
Sandy Hook, N. J.	16	4:30 p. m.	7:45 p. m.	0.90	4:53 p. m.	5:37 p. m.	0.02	0.08	0.23	0.37	0.46	0.48	0.57	0.63	0.67	0.74					
	17–18	6:24 p. m.	2:00 a. m.	1.28	7:19 p. m.	7:53 p. m.	0.01	0.11	0.35	0.61	0.75	0.79	0.88	0.94							
San Francisco, Calif.	(‡)			(‡)														(‡)			
San Jose, Calif.	(‡)			(‡)														(‡)			
San Luis Obispo, Calif.	19			0.03														T.			
Sante Fe, N. Mex.	8			0.60														0.42			
Sault Ste. Marie, Mich.	12			0.50														0.48			
Savannah, Ga.	2	12:57 p. m.	2:56 p. m.	1.09	1:04 p. m.	1:33 p. m.	0.02	0.10	0.29	0.53	0.68	0.78	0.84								
	26	1:15 p. m.	2:05 p. m.	0.53	1:31 p. m.	1:53 p. m.	0.01	0.16	0.35	0.36	0.47	0.51									
	27	8:52 p. m.	D.N. p.m.	1.13	9:19 p. m.	9:46 p. m.	0.03	0.10	0.31	0.49	0.66	0.79	0.83								
	28	3:45 p. m.	5:00 p. m.	0.54	4:08 p. m.	4:34 p. m.	0.02	0.13	0.21	0.30	0.38	0.46	0.50								
	29	4:05 p. m.	5:54 p. m.	0.83	4:34 p. m.	5:05 p. m.	0.01	0.17	0.35	0.47	0.59	0.69	0.75	0.77							
Scranton, Pa.	18	12:25 p. m.	1:47 p. m.	0.88	12:42 p. m.	1:16 p. m.	0.02	0.06	0.15	0.32	0.51	0.63	0.76	0.85							
Seattle, Wash.	27			0.35														0.17			
Sheridan, Wyo.	10			0.28														0.12			
Shreveport, La.	22	3:40 p. m.	7:40 p. m.	1.22	3:49 p. m.	4:20 p. m.	0.01	0.11	0.28	0.47	0.64	0.77	0.87	0.91							
Sioux City, Iowa	6			0.81														0.49			
Spokane, Wash.	29			1.08														0.46			
Springfield, Ill.	13	2:05 p. m.	3:05 p. m.	0.78	2:26 p. m.	2:47 p. m.	0.02	0.17	0.40	0.58	0.67	0.70									
	14–15	D. N. p. m.	7:34 a. m.	1.65	2:58 a. m.	3:28 a. m.	0.67	0.15	0.21	0.28	0.37	0.49	0.55								
Springfield, Mo.	19–20	9:02 p. m.	D. N. a. m.	1.69	9:26 p. m.	9:37 p. m.	0.05	0.36	0.58	0.61											
	30	2:37 p. m.	8:20 p. m.	1.78	3:02 p. m.	3:34 p. m.	0.07	0.24	0.46	0.53	0.70	0.88	1.05	1.09							
Syracuse, N. Y.	13	11:03 a. m.	12:00 noon	1.01	11:07 a. m.	11:30 a. m.	T.	0.34	0.64	0.78	0.86	0.94									
Tacoma, Wash.	29			0.45														0.10			
Tampa, Fla.	8	3:20 p. m.	4:25 p. m.	0.56	3:32 p. m.	3:46 p. m.	0.03	0.20	0.41	0.50											
	12	6:05 p. m.	6:45 p. m.	0.88	6:12 p. m.	6:32 p. m.	0.01	0.07	0.40	0.76	0.85										
Tatoosh Island, Wash.	26–27			2.30														(*)			
Taylor, Tex.	6–7	5:47 p. m.	9:00 a. m.	2.65	3:15 a. m.	5:16 a. m.	0.39	0.09	0.18	0.23	0.27	0.28	0.32	0.37	0.48	0.60	0.73	1.01	1.48	1.58	1.86
Terre Haute, Ind.	21			1.43														0.57			
Thomasville, Ga.	6	D. N. a. m.	7:34 a. m.	0.92	6:21 a. m.	6:41 a. m.	0.12	0.09	0.25	0.53	0.74										
Toledo, Ohio	16	7:06 a. m.	8:35 a. m.	3.65	7:14 a. m.	8:14 a. m.	0.01	0.09	0.12	0.32	0.75	1.17	1.74	2.34	2.93	3.20	3.38	3.58			
Tonopah, Nev.	2			0.92														(*)			
Topeka, Kans.	25	6:31 a. m.	8:17 a. m.	1.37	6:51 a. m.	7:50 a. m.	0.01	0.22	0.29	0.44	0.46	0.46	0.48	0.75	1.01	1.15	1.21	1.34			
Trenton, N. J.	11–12	10:30 p. m.	D.N. a. m.	0.64	10:33 p. m.	11:02 p. m.	0.01	0.13	0.15	0.24	0.43	0.57	0.62								
	17	6:40 p. m.	9:15 p. m.	0.84	6:45 p. m.	7:05 p. m.	0.01	0.13	0.33	0.56	0.64										
Valentine, Nebr.	28			0.92														0.31			
Vicksburg, Miss.	13	11:04 a. m.	2:30 p. m.	0.91	12:29 p. m.	1:02 p. m.	0.06	0.17	0.35	0.41	0.44	0.47	0.65	0.71	0.77						
	27	D.N. a. m.	7:50 a. m.	2.14	5:16 a. m.	6:22 a. m.	0.27	0.12	0.27	0.47	0.81	1.04	1.15	1.18	1.22	1.31	1.46	1.68	1.80		
Walla Walla, Wash.	29			0.52														0.26			
Washington, D. C.	1	4:31 p. m.	6:35 p. m.	0.96	4:31 p. m.	4:45 p. m.	0.00	0.37	.071	0.85											
Wausau, Wis.	8			0.86														0.40			
Wichita, Kans.	20	D.N. a. m.	6:20 a. m.	0.98	3:33 a. m.	4:08 a. m.	0.02	0.19	0.33	0.35	0.42	0.53	0.66	0.73							
	31–1	5:05 p. m.	D. N. a. m.	1.43	6:37 p. m.	7:02 p. m.	0.40	0.18	0.32	0.51	0.61	0.70									
Williston, N. Dak.	29			0.70														0.26			
Wilmington, N. C.	1	9:35 p. m.	D. N. p. m.	1.03	9:37 p. m.	10:17 p. m.	0.01	0.17	0.31	0.38	0.46	0.55	0.61	0.71	0.88						
	20	5:35 p. m.	8:50 p. m.	1.46	6:13 p. m.	6:51 p. m.	0.03	0.23	0.55	0.78	0.81	0.87	1.08	1.27	1.34						
Winnemucca, Nev.	26			0.28														0.18			
Wytheville, Va.	12	12:05 p. m.	1:55 p. m.	0.71	12:10 p. m.	12:26 p. m.	0.03	0.16	0.37	0.49	0.52										
	14	12:25 p. m.	2:00 p. m.	1.25	12:38 p. m.	1:40 p. m.	0.01	0.14	0.29	0.51	0.71	0.77	0.77	0.80	0.85	0.88	0.91	1.16	1.24		
	18	11:50 a. m.	12:45 p. m.	1.05	12:10 p. m.	12:45 p. m.	0.03	0.19	0.34	0.50	0.71	0.94	0.95	1.02							
Yankton, S. Dak.	28	4:35 p. m.	6:05 p. m.	1.37	4:49 p. m.	5:41 p. m.	0.03	0.09	0.24	0.29	0.31	0.40	0.62	0.71	0.89	1.11	1.21	1.28			
Yellowstone Park, Wyo.	10			0.32														0.17			

‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, August, 1920.*

Stations.	Altitude above mean sea level Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F*	° *F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.88	30.01	+0.05	64.2	+4.4	72.2	56.2	86	40	1.78	−2.30	0.0
Sydney, C. B. I.	48	30.04	30.09	+ .14	68.7	+5.4	77.6	59.8	90	48	3.02	−0.60	0.0
Halifax, N. S.	88	29.98	30.08	+ .08	65.7	+2.1	74.4	57.1	87	44	6.01	+1.66	0.0
Yarmouth, N. S.	65	30.00	30.07	+ .10	60.3	+0.1	68.5	52.0	77	45	2.53	−1.48	0.0
Charlottetown, P. E. I.	38	30.00	30.04	+ .10	68.7	+4.4	76.8	60.5	88	46	4.06	+0.32	0.0
Chatham, N. B.	28	30.02	30.05	+ .12	67.8	+4.6	78.0	57.7	94	46	4.36	+0.32	0.0
Father Point, Qne.	20	29.99	30.01	+ .10	55.8	+0.2	64.6	47.1	78	36	2.90	−0.15	0.0
Quebec, Que.	296	29.74	30.06	+ .13	66.6	+3.5	76.2	57.0	86	45	4.21	+0.38	0.0
Montreal, Que.	187	29.84	30.04	+ .09	70.2	+3.8	79.3	61.2	90	50	3.79	+0.22	0.0
Stonecliffe, Ont.	489	29.44	30.04	+ .08	58.9	−4.3	80.8	37.1	92	24	1.27	−1.68	0.0
Ottawa, Ont.	236	29.79	30.06	+ .10	69.9	+5.1	81.3	58.5	93	48	2.54	−0.49	0.0
Kingston, Ont.	285	29.74	30.04	+ .06	69.6	+2.6	77.3	61.9	83	51	2.07	−0.31	0.0
Toronto, Ont.	379	29.64	30.03	+ .04	69.8	+3.8	79.6	60.1	89	48	0.99	−1.77	0.0
Cochrane, Ont.	930												
White River, Ont.	1,244	28.74	30.03	+ .07	58.2	+1.8	74.1	42.3	84	25	2.03	−1.27	0.0
Port Stanley, Ont.	592	29.43	30.06	+ .06	66.9	+1.0	75.1	58.8	82	45	1.41	−1.01	0.0
Southampton, Ont.	656	29.35			65.3	+1.5	73.8	56.8	84	39	1.89	−0.36	0.0
Parry Sound, Ont.	688	29.39	30.07	+ .09	67.2	+3.7	78.6	55.7	87	42	1.92	−0.80	0.0
Port Arthur, Ont.	644	29.36	30.08	+ .12	61.7	+2.2	71.5	52.0	86	38	1.76	−0.99	0.0
Winnipeg, Man.	760												
Minnedosa, Man.	1,690	28.16	29.94	.00	66.4	+7.0	81.5	51.3	97	28	2.10	0.00	0.0
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.69	29.89	− .04	66.0	+4.5	81.2	50.9	96	30	1.83	+0.19	0.0
Medicine Hat, Alb.	2,144	27.63	29.83	− .09	70.6	+4.9	85.9	55.3	95	45	0.23	−1.44	0.0
Moose Jaw, Sask.	1,759												
Swift Current, Sask.	2,392	27.38	29.94	+ .01	68.0	+4.6	84.2	51.7	102	38	1.02	−0.89	0.0
Calgary, Alb.	3,428	26.46	29.97	+ .06	62.7	+3.3	78.8	46.6	92	31	0.09	−2.05	0.0
Banff, Alb.	4,521	25.45	29.94	+ .03	59.0	+2.7	76.0	42.0	89	28	0.27	−2.26	0.0
Edmonton, Alb.	2,150	27.67	29.92	.00	59.4	+0.6	72.8	46.1	85	34	1.97	−0.16	0.0
Prince Albert, Sask.	1,450	28.36	29.91	− .01	65.2	+6.3	78.6	51.9	92	40	2.62	+0.47	0.0
Battleford, Sask.	1,592	28.18	29.90	− .01	62.8	+0.2	75.2	50.4	91	35	2.79	+0.43	0.0
Kamloops, B. C.	1,262	28.74	30.00	+ .09	69.5	+0.9	83.7	55.4	97	43	1.18	+0.09	0.0
Victoria, B. C.	230	29.78	30.03	+ .02	61.0	+2.3	69.9	52.3	84	46	1.61	+1.01	0.0
Barkerville, B. C.	4,180	25.74	30.03	+ .13	52.5	−3.8	64.6	40.3	76	30	3.28	+0.18	0.0
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												

SEISMOLOGICAL REPORTS.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, D. C., Oct. 3, 1920.]

TABLE 1.—*Noninstrumental earthquake reports, August, 1920.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1920.	*H. m.*		° ′	° ′			*Sec.*			
Aug. 18	7 20	Salinas	36 36	121 40	3	1	5	None	Felt by many	Dr. E. D. Eddy.
23	23 10	Los Angeles	34 03	118 15	4	2-3		do	Felt by several	P. Hansen.
		MONTANA.								
16	18 05	Helena	46 40	112 00	3	1	2 ca.	do	do	N. T. Lathrop.
		SOUTH CAROLINA.								
1	11 53	Summerville	33 04	80 15	2	1			do	E. P. Lawton.
		UTAH.								
18	8 20	Beaver	38 12	112 45	3	1	5-6	Rumbling	Traveled from SW. to NE	C. T. Baldwin.

TABLE 2.—*Instrumental reports, August, 1920.*

[For significance of symbols and abbreviations, and for a description of stations and instruments, see the REVIEW for January, 1920, pp. 62-63.]

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			ALASKA. *U. S. C. & G. S. Magnetic Observatory, Sitka.*					
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 26		e_N	23 08 16					E not in operation. No distinct M.
		M_N				20		
		F_N	23 19 —					
			ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*					
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 3		eP_E	20 09 08					Times uncertain, due to failure of marking apparatus. Preliminary tremors faint in both components.
		eP_N	20 09 44					
		eS_E	20 17 29					
		eS_N	20 19 01					
		L_E	20 28 29	32				
		M_E	20 30 45	20	10			
		C_E	20 41 —	16				
		F_E	21 08 —	13				
		F_N	20 39 —					
15		eP_E	8 29 27					Not apparent on N. Preliminary tremors faint.
		S_E	8 40 13					
		L_E	8 58 20					
		M_E	9 02 45	21	10			
		C_E	9 20 —	16				
		F_E	9 28 —	16				
20		L_E	16 54 07					Record on N barely perceptible.
		L_N	16 55 04					
		M_E	17 00 52	14	10			
		C_E	17 02 —					
		F_E	17 14 —					
		F_N	17 01 —					
26		eP_E	23 08 25					Preliminary tremors faint on both components. Nothing else on N.
		eP_N	23 08 24					
		eL_E	23 23 50	20				
		M_E	23 27 25	17	10			
		C_E	23 32 —	15				
		F_E	23 58 —					
		F_N	23 12 —					
29		P_N	12 50 18					
		L_E	12 53 55					
		L_N	12 55 06					
		M_E	12 55 57	8	20			
		M_N	12 56 52	7		10		
		C_E	13 00 —					
		C_N	12 58 —					
		F_E	13 05 —					
		F_N	13 03 —					

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. N_N	Distance.	Remarks.
			CALIFORNIA. *Theosophical University, Point Loma.*					
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 1					200	300		Tremors during 24h. preceding 15h. on dates given.
2					200	200		
3					200	300		
4					50	100		
8					100	100		
15					100	100		
18					200	300		
21					100	100		
23					100	100		
25					100	100		
28					200	200		
29					100	100		
30					50	50		
31					100	100		
			DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*					
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 2		eL	19 39 30	30				Quake on Aug. 3 inserted in July report by mistake, instead of this quake.
		L	19 48 —	20				
		L	19 55 —	18				
		F	20 15 *ca.*					
2		P	21 56 27					
		S?	21 59 15					
		F	22 20 *ca.*					
Aug. 3		P?	3 21 08					Amplitudes small.
		S	3 24 15					
		F	3 35 *ca.*					
3		P	20 08 08				7,400	
		S	20 16 58					
		L_N	20 31 35					
		L_E	20 29 00					
		L	20 36 —	20				
		L	20 45 —	16				
		F	21 30 *ca.*					
12		P	6 27 12				3,500	
		S	6 32 30					
		L	6 36 10	18				
		F	6 45 *ca.*					
13		P	2 12 46					
		S	2 20 46				6,000	
		eL	2 33 30					
		F	2 40 *ca.*					

TABLE 2.—*Instrumental reports, August, 1920*—Continued.

DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington*—Continued.

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 15	.....	P.....	8 36 *ca.*	.....	.....	.....	..8,800	
		S.....	8 46 *ca.*	.....	.....	.....	.....	
		eL....	9 10 —	.....	.....	.....	.....	
		L.....	9 18 —	20	.....	.....	.....	
		L.....	9 24 —	16	.....	.....	.....	
		F.....	9 50 —	.....	.....	.....	.....	
20	.....	P.....	16 27 25	.....	.....	.....	..8,500	
		S.....	16 37 08	.....	.....	.....	.....	
		L.....	16 52 25	.....	.....	.....	.....	
		L.....	16 52 —	20	.....	.....	.....	
		F.....	17 30 —	.....	.....	.....	.....	
26	.....	P.....	23 10 14	.....	.....	.....	..6,800	
		S.....	23 18 30	.....	.....	.....	.....	
		eL....	23 29 52	.....	.....	.....	.....	Period not well defined.
27	.....	F.....	0 15 —	.....	.....	.....	.....	

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 3	.....	S.....	20 22 36	17	.....	.....	.....	First phase called S after comparison with Cheltenham and Tucson.
		e.....	20 39 48	.....	.....	.....	.....	
		L.....	20 45 48	.....	.....	.....	.....	
		M.....	20 50 18	17	*700	.....	.....	
		C.....	21 03 —	17	.....	.....	.....	
		F.....	22 45 —	17	.....	.....	.....	
15	.....	iP.....	8 25 18	17	.....	.....	.....	
		iS.....	8 32 06	17	.....	.....	.....	
		eL.....	8 39 00	19	.....	.....	.....	
		M.....	8 49 00	17	*3,000	.....	.....	
		C.....	8 54 —	17	.....	.....	.....	
		F.....	9 53 —	17	.....	.....	.....	
17	.....	e.....	2 54 00	.....	.....	.....	.....	Slight record.
		M.....	3 02 30	18	*200	.....	.....	
		F.....	3 08 —	.....	.....	.....	.....	
20	.....	e.....	17 48 —	.....	.....	.....	.....	On account of failure of driving clock only the end portion of this quake was recorded.
		F.....	20 10 —	.....	.....	.....	.....	
25	.....	P.....	22 04 30	17	.....	.....	.....	
		S.....	22 12 54	17	.....	.....	.....	
		L.....	22 22 00	30	.....	.....	.....	
		M.....	22 31 42	17	*800	.....	.....	
		C.....	22 37 —	17	.....	.....	.....	
		F.....	23 04 —	17	.....	.....	.....	
26	.....	eP.....	23 07 48	.....	.....	.....	.....	
		S.....	23 12 00	17	.....	.....	.....	
		eL.....	23 16 00	17	.....	.....	.....	
		M.....	23 20 48	17	*1,100	.....	.....	
		C.....	23 29 —	17	.....	.....	.....	
		F.....	24 45 —	17	.....	.....	.....	
27	.....	eP.....	3 48 18	.....	.....	.....	.....	
		eL.....	4 05 00	17	.....	.....	.....	
		M.....	4 09 48	17	*300	.....	.....	
		C.....	4 16 —	17	.....	.....	.....	
		F.....	4 25 —	17	.....	.....	.....	
29	.....	P.....	11 05 18	17	.....	.....	.....	
		L.....	11 12 18	30	.....	.....	.....	
		M.....	11 20 48	19	*500	.....	.....	
		C.....	11 24 —	18	.....	.....	.....	
		F.....	11 30 —	.....	.....	.....	.....	

*Trace amplitude.

ILLINOIS. *U. S. Weather Bureau, Chicago.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 2	.....	e.....	6 20 00	.....	.....	.....	.....	
		L.....	6 35 —	18	.....	.....	.....	
		F.....	7 05 *ca.*	.....	.....	.....	.....	
3	.....	eP.....	3 21 22	.....	.....	.....	.....	
		PR1...	3 27 07	.....	.....	.....	.....	
		S?.....	3 31 52	.....	.....	.....	.....	
		eL.....	3 52 40	.....	.....	.....	.....	
		L.....	4 10—	20	.....	.....	.....	
		F.....	5 20 *ca.*	.....	.....	.....	.....	
3	.....	P.....	20 08 00	.....	.....	.....	..7,700	
		S.....	20 17 05	.....	.....	.....	.....	
		L.....	20 29 —	.....	.....	.....	.....	
		L.....	20 33 —	30	.....	.....	.....	
		L.....	20 40 —	20	.....	.....	.....	
		F.....	24 *ca.*	.....	.....	.....	.....	
12	.....	P.....	6 27 55	.....	.....	.....	..4,300	
		S.....	6 34 00	.....	.....	.....	.....	
		L.....	6 39 12	.....	.....	.....	.....	
		L.....	6 41 —	20	.....	.....	.....	
		F.....	7 20 *ca.*	.....	.....	.....	.....	
12	.....	e.....	21 23 —	.....	.....	.....	.....	May not be seismic.
		L?....	21 38 —	.....	.....	.....	.....	
		F.....	23 *ca.*	.....	.....	.....	.....	
13	.....	P.....	2 12 41	.....	.....	.....	..6,900	
		S.....	2 21 04	.....	.....	.....	.....	
		eL.....	2 35 —	.....	.....	.....	.....	
		L.....	2 43 —	18	.....	.....	.....	
		F.....	4 *ca.*	.....	.....	.....	.....	
15	.....	e.....	0 50 —	.....	.....	.....	.....	
		L.....	0 57 —	16	.....	.....	.....	
		F.....	1 30 *ca.*	.....	.....	.....	.....	
15	.....	P?....	8 33 58	.....	.....	.....	.....	
		S.....	8 44 *ca.*	.....	.....	.....	.....	
		L.....	9 10 —	26	.....	.....	.....	
		L.....	9 18 —	18	.....	.....	.....	
		F.....	11 10 *ca.*	.....	.....	.....	.....	
20	.....	P.....	16 26 50	.....	.....	.....	..8,900	
		S.....	16 36 56	.....	.....	.....	.....	
		L.....	16 54 15	.....	.....	.....	.....	
		L.....	17 01 —	24	.....	.....	.....	
		L.....	18 — —	18	.....	.....	.....	
		F.....	20 20 *ca.*	.....	.....	.....	.....	
26	.....	P.....	23 08 10	.....	.....	.....	..5,800	
		S.....	23 15 33	.....	.....	.....	.....	
		L.....	23 24 15	22	.....	.....	.....	
		L.....	23 32 —	16	.....	.....	.....	
27	.....	F.....	1 30 *ca.*	.....	.....	.....	.....	
27	.....	eL.....	13 54 30	.....	.....	.....	.....	May not be seismic.
		L.....	14 01 45	18	.....	.....	.....	
		F.....	14 30 *ca.*	.....	.....	.....	.....	
29	.....	eL^E...	11 42 30	.....	.....	.....	.....	
		L^E....	11 46 30	18	.....	.....	.....	Nothing on NS.
		F.....	12 10 *ca.*	.....	.....	.....	.....	
29	.....	e.....	13 00 00	.....	.....	.....	.....	Phases indistinguishable F lost in changing sheets.
		F.....	.....	.....	.....	.....	.....	

TABLE 2.—*Instrumental reports, August, 1920*—Continued.

MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 3	.....	eP^E	20 08 10	.....	.....	.....	.....	P tremors only on E.
		eP^N	20 08 05	.....	.....	.....	.....	
		eS^E	20 16 59	.....	.....	.....	.....	
		S^N	20 16 49	.....	.....	.....	.....	
		L^N	20 31 33	30	.....	.....	.....	
		M^N	20 38 07	18	.....	20	.....	
		C^N	20 47 —	.....	.....	.....	.....	
		F^E	20 25 —	.....	.....	.....	.....	
		F^N	21 03 —	16	.....	.....	.....	
20	.....	eP^N	16 27 29	3	.....	.....	.....	No distinct M. Not apparent on E.
		S_N	16 37 16	.....	.....	.....	.....	
		eL^N	17 03 58	.....	.....	.....	.....	
		M^N	.....	.....	.....	10	.....	
		F^N	17 21 —	.....	.....	.....	.....	
26	.....	eP^E	23 10 15	.....	.....	.....	.....	Preliminary tremors only on E.
		eP^N	23 10 17	.....	.....	.....	.....	
		eS^N	23 18 38	.....	.....	.....	.....	
		M^N	23 31 45	12	.....	10	.....	
		L^N	23 31 00	.....	.....	.....	.....	
		C^N	23 41 —	.....	.....	.....	.....	
		F^E	23 16 —	.....	.....	.....	.....	
		F^N	24 01 —	.....	.....	.....	.....	

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 3	.....	$PR1^N$	20 07 12	.....	.....	.....	.....	This interpretation adopted after comparison with Cheltenham record.
		S^E	20 12 13	12	.....	.....	.....	
		eS^N	20 12 06	.....	.....	.....	.....	
		$SR1^E$	20 15 33	.....	.....	.....	.....	
		$SR1^N$	20 15 50	.....	.....	.....	.....	SR1 prominent in both components.
		L^E	20 20 17	32	.....	.....	.....	
		eL^N	20 21 47	14	.....	.....	.....	
		M^E	20 22 18	20	250	.....	.....	
		M^N	20 26 25	16	.....	30	.....	
		C^E	20 27 —	13	.....	.....	.....	
		C^N	20 29 —	16	.....	.....	.....	
		F^E	20 45 —	13	.....	.....	.....	
		F^N	20 36 —	9	.....	.....	.....	
7	.....	P^E	2 41 41	.....	.....	.....	.....	Apparently slight close shock.
		P^N	2 41 21	.....	.....	.....	.....	
		M^E	.....	.....	15	.....	.....	No distinct M.
		M^N	.....	.....	.....	15	.....	
		F^E	2 45 —	.....	.....	.....	.....	
		F^N	2 47 —	.....	.....	.....	.....	
20	.....	S^E	16 33 09	.....	.....	.....	.....	First appearance seems to be S from comparison with Cheltenham.
		eL^E	16 42 00	.....	.....	.....	.....	
		e^N	16 52 06	.....	.....	.....	.....	
		M^E	16 46 50	26	20	.....	.....	L_E difficult to place.
		M^N	.....	.....	.....	10	.....	
		C^E	16 52 —	18	.....	.....	.....	
		F^E	17 10 —	.....	.....	.....	.....	
		F^N	16 56 —	.....	.....	.....	.....	

CANAL ZONE. *Panama Canal, Balboa Heights.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 3	.....	P^N	20 04 38	.....	.....	.....	.....	Dist. about 4,000 km., probably NW.
		S^E	20 10 36	.....	.....	.....	.....	
		S^N	20 10 30	.....	.....	.....	.....	
		M^E	20 23 02	.....	*500	.....	.....	
		M^N	20 23 44	.....	.....	*1,000	.....	
		F^E	21 05 00	.....	.....	.....	.....	
		F^N	21 08 00	.....	.....	.....	.....	

*Trace amplitude.

VERMONT. *U. S. Weather Bureau, Northfield.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 3	.....	L.....	20 36 30	18	.....	.....	.....	Other phases lost in unsteadiness due to loose joint.
		F.....	20 50 *ca*	.....	.....	.....	.....	

CANADA. *Dominion Observatory, Ottawa.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 3	.....	e?.....	3 23 04	.....	.....	.....	.....	Small disturbance, resembling micros.
		F.....	4 40 *ca*	.....	.....	.....	.....	
3	.....	O.....	19 57 20	.....	.....	.....	8,140	
		P_N.....	20 08 48	.....	.....	.....	.....	
		S_E.....	20 18 15	.....	.....	.....	.....	
		eL.....	20 31 30	40	.....	.....	.....	
		L.....	20 40 —	21	.....	.....	.....	
		L.....	20 51 —	15	.....	.....	.....	
		F.....	21 30 —	.....	.....	.....	.....	
13	.....	i_N.....	2 13 30	.....	.....	.....	.....	Irregular short periods of 2-4 secs. closely resembling micros. May not be seismic.
		i_N.....	2 14 06	.....	.....	.....	.....	
		e.....	2 16 27	.....	.....	.....	.....	
		i or L.	2 22 08	.....	.....	.....	.....	
		i.....	2 22 50	.....	.....	.....	.....	
		i.....	2 24 00	.....	.....	.....	.....	
		F.....	3 50 —	.....	.....	.....	.....	
15	.....	O.....	8 22 08	.....	.....	.....	10,000	
		eP.....	8 35 10	.....	.....	.....	.....	
		S_E.....	8 46 08	.....	.....	.....	.....	
		SR_{1E}..	8 52 42	.....	.....	.....	.....	
		eL.....	9 07 —	33	.....	.....	.....	
		L_E.....	9 26 —	18	.....	.....	.....	
		L_E.....	9 29 —	17	.....	.....	.....	
		L_E.....	9 39 —	16	.....	.....	.....	
		L_E.....	10 00 —	15	.....	.....	.....	
		LR_{1E}..	10 31 —	20	.....	.....	.....	
		F.....	10 40 —	.....	.....	.....	.....	
20	.....	O?.....	16 15 43	.....	.....	.....	(9,140)	Phases do not agree very well in giving dist.
		$e?_N$.....	16 22 30	.....	.....	.....	.....	
		iP?.....	16 28 03	.....	.....	.....	.....	
		iS?.....	16 38 21	.....	.....	.....	.....	
		e_E.....	16 43 20	.....	.....	.....	.....	
		eL_E?..	16 52 30	40	.....	.....	.....	
		L.....	17 09 —	18	.....	.....	.....	
		L.....	17 17 to	13	.....	.....	.....	
		L.....	17 25 —	.....	.....	.....	.....	
		L_E.....	17 36 —	12	.....	.....	.....	
		L_E.....	18 00 —	13	.....	.....	.....	
		L_E.....	18 20 —	13	.....	.....	.....	
		F.....	18 30 —	.....	.....	.....	.....	
21	.....	e_E.....	21 26 26	.....	.....	.....	.....	
		L.....	21 37 —	11	.....	.....	.....	
		F.....	21 51 —	.....	.....	.....	.....	
26	.....	O.....	23 00 04	.....	.....	.....	6,200	
		iP.....	23 09 46	.....	.....	.....	.....	
		PR_{1E}..	23 12 13	.....	.....	.....	.....	
		eS.....	23 17 33	.....	.....	.....	.....	
		eL?...	23 27 30	.....	.....	.....	.....	
		L.....	23 31 —	24	.....	.....	.....	
		L_E.....	23 44 —	18	.....	.....	.....	
27	.....	L_E.....	0 05 —	13	.....	.....	.....	
		L_E.....	0 25 —	12	.....	.....	.....	
		F.....	1 00 —	.....	.....	.....	.....	
29	.....	eL_E....	11 50 23 to 12 05 —	21	.....	.....	.....	

No earthquakes were recorded during August, 1920, at the following stations:

COLORADO. *Sacred Heart College*, Denver.

Reports for August, 1920, have not been received from the following stations:

ALABAMA. *Spring Hill College*, Mobile.
DISTRICT OF COLUMBIA. *Georgetown University*. Washington.
MASSACHUSETTS. *Harvard University*. Cambridge.
MISSOURI. *St. Louis University*. St. Louis.
NEW YORK. *Canisius College*, Buffalo; *Cornell University*, Ithaca; *Fordham University*, New York.
CANADA. *Dominion Meteorological Service*. Victoria and Toronto.

SEISMOLOGICAL DISPATCHES[1]

Kingston, Jamaica, July 2, 1920:
Kingston and St. Andrew were shaken by an earthquake at 12:20 last night. No damage is reported.—Associated Press.
Victoria, B. C., July 7, 1920:
A well-defined record on the Gonzales Observatory seismograph here to-day indicated an earthquake about 550 miles south of Victoria. The disturbance began at 10:45 a. m. and continued 20 minutes.—Associated Press.
Los Angeles, Calif., July 16, 1920:
A severe earthquake at 10:10 o'clock this morning apparently centered in Los Angeles city, caused slight damage to some of the older buildings, broke a number of plate-glass windows, and frightened the citizens generally. No extensive damage was reported.—Associated Press.
Luray, Va., July 25, 1920:
Following an earthquake, this county, at a late hour yesterday evening, was visited by one of the most severe electrical storms ever known. A short time before the storm struck the county the second most severe earthquake ever known here was experienced. In Luray it was particularly severe, rattling windows and doors.—International News Service.
Santiago, Chile, July 26, 1920:
This city was rocked by a strong earthquake at 12:30 o'clock this morning, but little damage has been reported. It was felt throughout the central zone of the country from Serena to Conception. The duration of the shock is estimated here at from 4 to 6 seconds.
Advices from Argentina say an earthquake occurred at Mendoza last night, lasting nearly 2 minutes.
Other estimates of the duration of the shock here vary, some reaching 25 seconds. An investigation revealed small damage to cornices and plaster walls of some buildings.
Dispatches from Valparaiso say that the earthquake produced considerable alarm there.
This morning's quake was the most intense since 1906. It appears to have been stronger at Valparaiso than at Santiago.—Associated Press.
Los Angeles, Calif., July 26, 1920.
A sharp earthquake shock awoke Los Angeles at 4:12 this morning. A few chimneys were knocked down, dishes broken, and windows rattled.—Associated Press.
Mexico City, August 19:
The volcano of Popocatepetl is showing signs of activity, luminous smoke being visible above its crater and ashes falling on the neighboring town of Ayotzingo, in the State of Mexico.—Associated Press.

[1] Collected by seismological station, Georgetown University, Washington, D. C.

Santiago, Chile, August 21:
A series of violent earthquakes visited the southern region of Chile Friday, causing considerable alarm, but so far as has been ascertained little property damage. The shocks were most intense in the Provinces of Malleco and Cautin, and lasted for about a minute. Twenty shocks were reported on the sparsely populated island of Mocha, off the Province of Malleco between 11 a. m. and 4 p. m. Friday, and lighthouses on the island were damaged. No fatalities have been reported.—Associated Press.
San Salvador, Republic of Salvador, August 27:
The volcano San Miguel is throwing out sand and ashes. No damages have been reported.—Associated Press.
London, August 29:
The island of Malta suffered an earthquake shock of considerable force at 2.45 o'clock this morning, says a Central News dispatch from Rome, quoting advices from Syracuse, Sicily. Numerous buildings in Floriana and the surrounding district were seriously damaged and the population was in a panic, the dispatch says.—Associated Press.

TABLE 3.—*Late reports (instrumental).*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
DISTRICT OF COLUMBIA. *Georgetown University, Washington.*								
1920			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 2	.....	eL_N	19 39 30	.....	.....	.....	.....	Heavy micros.
		L_E	19 45 31	23	.....	.....	.....	
		L_N	19 45 15	23	.....	.....	.....	
		F	19 57 —	.....	.....	.....	.....	
2	.....	e_E	21 30 25	.....	.....	.....	.....	Very heavy micros; doubtful.
		e_N	21 30 25	.....	.....	.....	.....	
		S?	21 39 25	.....	.....	.....	.....	
		i_N	21 57 20	.....	.....	.....	.....	
		F	22 25 —	.....	.....	.....	.....	
7	.....	eP_E	18 49 40	.....	.....	.....	.....	Micros.
		eP_N	18 49 40	.....	.....	.....	.....	
		$S?_E$	18 56 30	.....	.....	.....	.....	
		$S?_N$	18 56 20	.....	.....	.....	.....	
		eL_E	19 04 12	7	.....	.....	.....	
		eL_N	19 04 24	7	.....	.....	.....	
		M_E	19 05 20	6	*10,500	.....	.....	
		M_N	19 05 25	6	.....	*5,700	.....	
		F	19 50 —	.....	.....	.....	.....	
7	.....	e	20 02 —	.....	.....	.....	.....	Micros.
		F	20 11 —	.....	.....	.....	.....	
26	.....	e	5 23 58	.....	.....	.....	.....	Very heavy micros.
		S?	5 33 17	.....	.....	.....	.....	
		F	6 *ca.* —	.....	.....	.....	.....	

*Trace amplitude.

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 7	.....	eP_E	0 44 44	.....	.....	.....	.....	
		eP_N	0 44 54	.....	.....	.....	.....	
		L_N	0 45 20	.....	.....	.....	.....	
		M_E	0 45 45	.....	25	.....	.....	
		M_N	0 45 40	.....	.....	25	.....	
		F_E	0 50 —	.....	.....	.....	.....	
		F_N	0 49 —	.....	.....	.....	.....	

Chart I. Hydrographs of Several Principal Rivers, August, 1920.

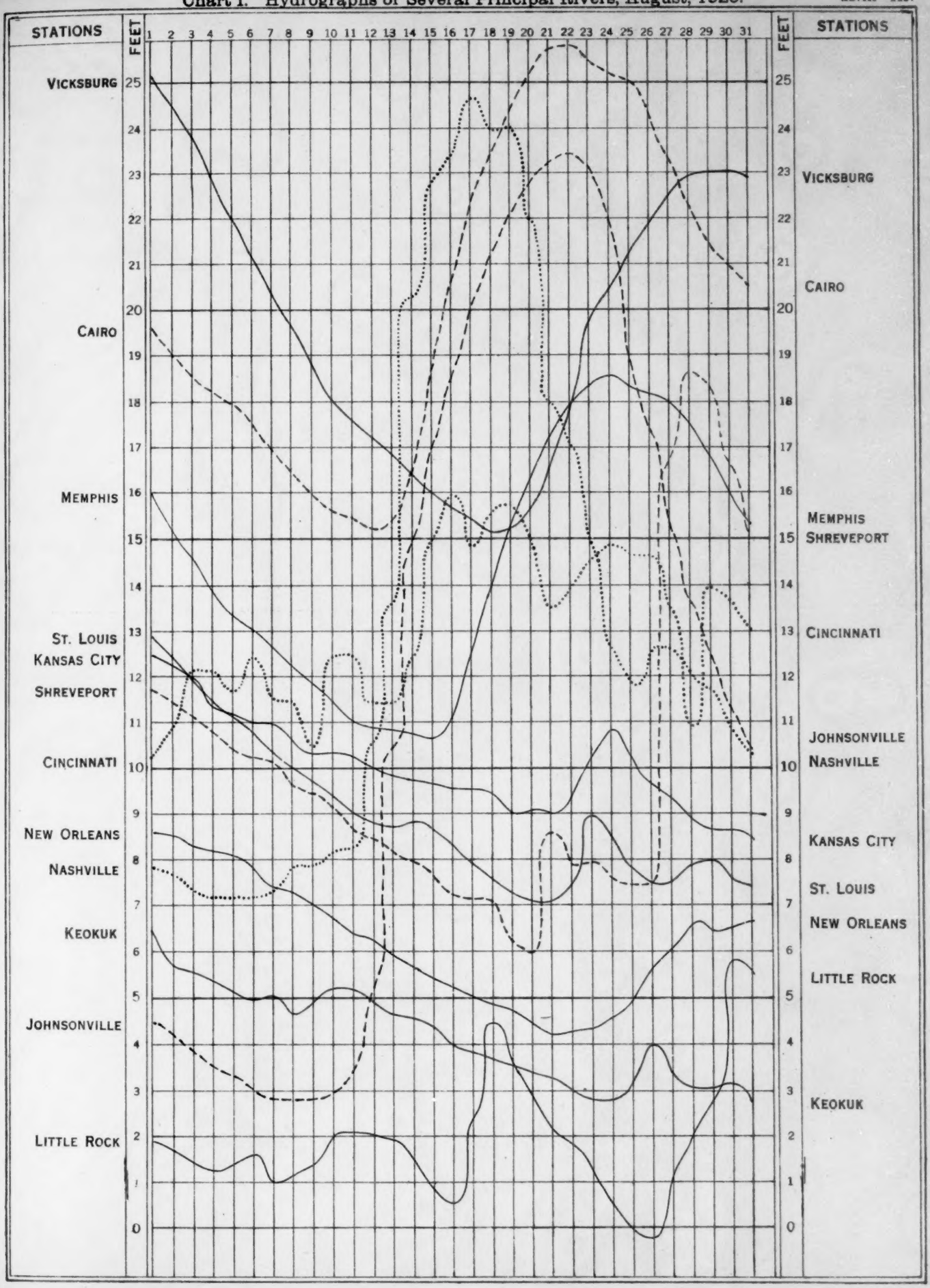


Chart II. Tracks of Centers of High Areas, August, 1920.

(Plotted by Herbert Lyman.)

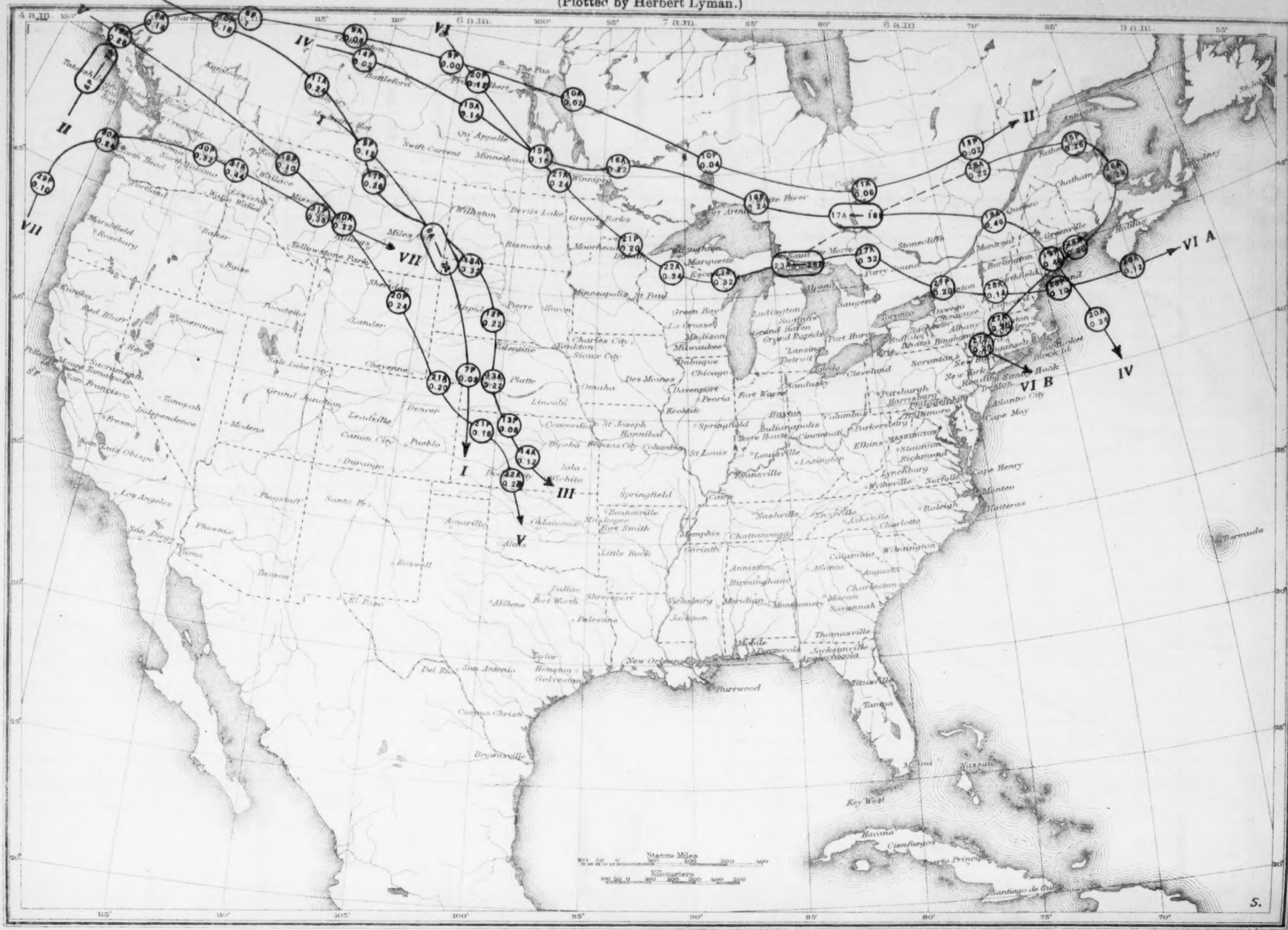


Chart III. Tracks of Centers of Low Areas, August, 1920.

Chart III. Tracks of Centers of Low Areas, August, 1920.

(Plotted by Herbert Lyman.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, August, 1920.

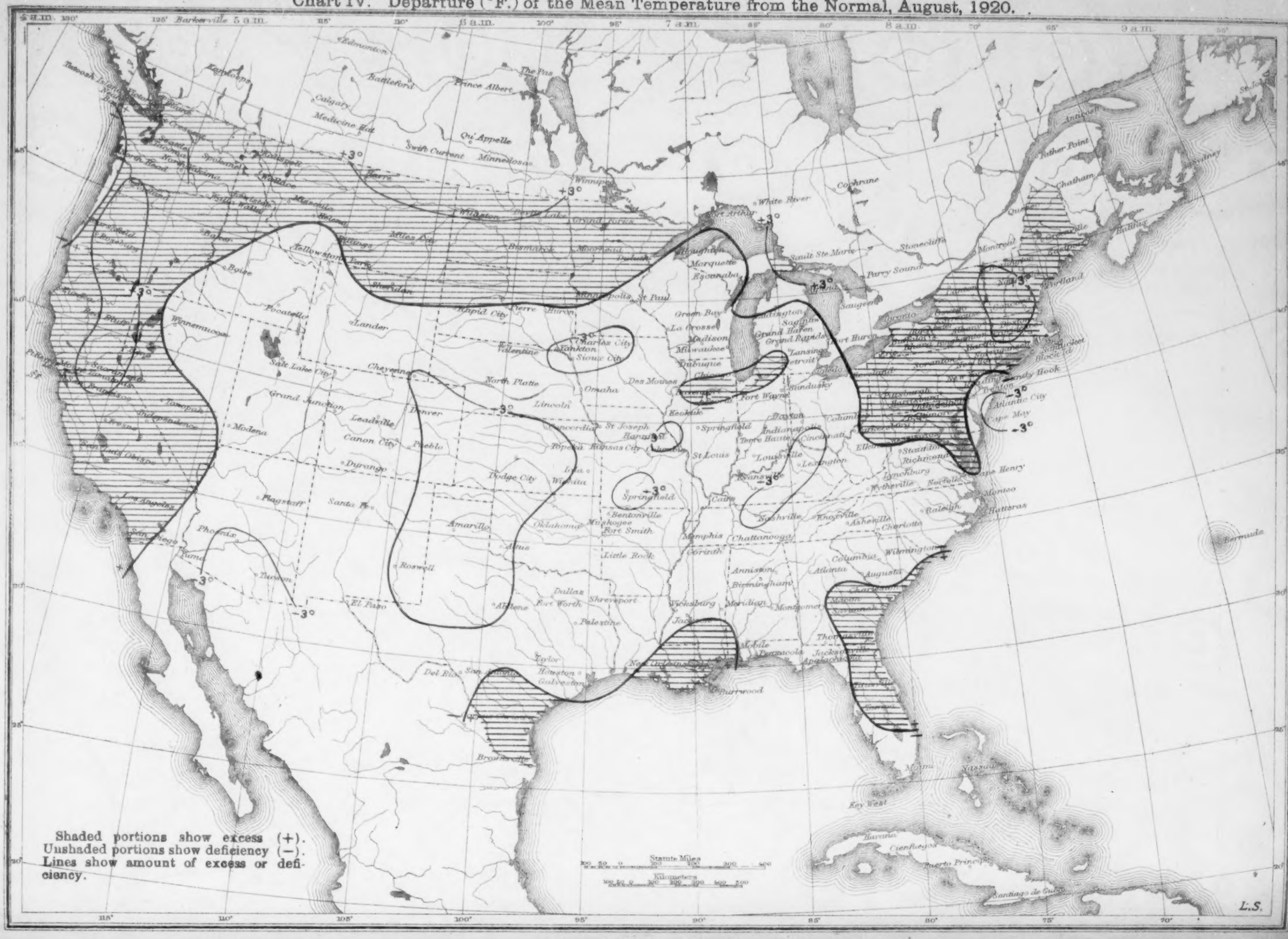


Chart V. Total Precipitation, Inches, August, 1920.

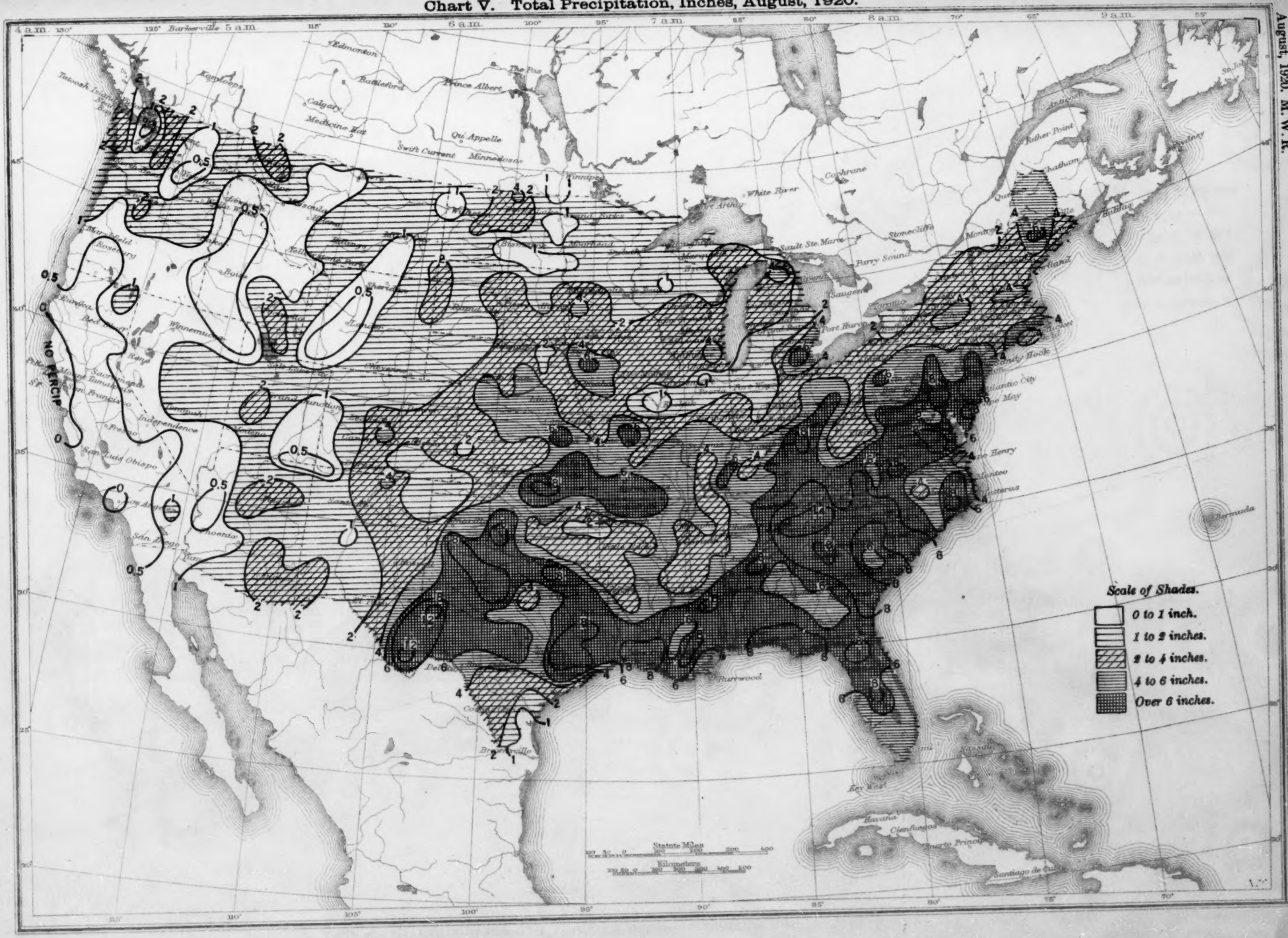


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, August, 1920.

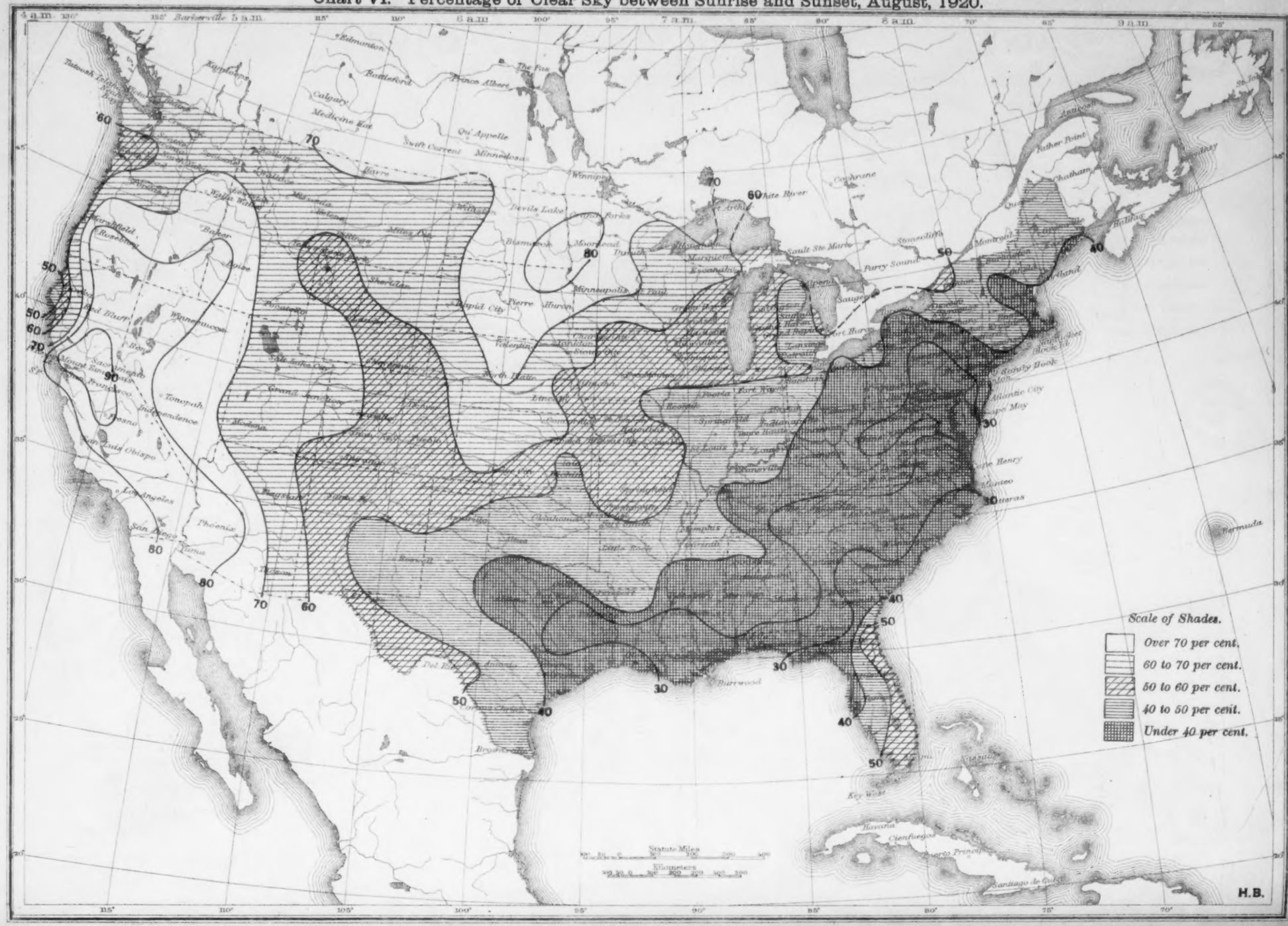

4 a.m.
5 a.m.
6 a.m.
7 a.m.
8 a.m.
9 a.m.
Barkerville
Edmonton
Kamloops
Battleford
Calgary
Medicine Hat
Prince Albert
The Pas
Qu'Appelle
Swift Current
Minnedosa
Winnipeg
Devils Lake
Bismarck
Moorhead
Minneapolis
St. Paul
Pierre
Huron
Rapid City
Valentine
Grand Island
Omaha
Des Moines
Kansas City
Topeka
Lincoln
Concordia
Dodge City
Amarillo
Oklahoma
Fort Worth
Abilene
Austin
San Antonio
Del Rio
Corpus Christi
Brownsville
Galveston
Houston
Beaumont
Shreveport
Little Rock
Memphis
Meridian
Vicksburg
Mobile
New Orleans
Montgomery
Atlanta
Birmingham
Chattanooga
Nashville
Louisville
Cincinnati
Columbus
Indianapolis
Springfield
Peoria
Chicago
Milwaukee
Madison
Green Bay
Marquette
Duluth
Moose Jaw
Medicine Hat
Swift Current
Prince Albert
Battleford
Edmonton
Kamloops
Tatoosh Island
Walla Walla
Spokane
Lewiston
Boise
Pocatello
Helena
Miles City
Billings
Havre
Williston
Minot
Devils Lake
Grand Forks
Fargo
Bismarck
Mandan
Huron
Pierre
Rapid City
Valentine
North Platte
Grand Island
Omaha
Lincoln
Concordia
Topeka
Kansas City
Dodge City
Amarillo
Abilene
Fort Worth
Austin
San Antonio
Del Rio
Corpus Christi
Brownsville
Galveston
Houston
Beaumont
Shreveport
Little Rock
Memphis
Meridian
Vicksburg
Mobile
New Orleans
Montgomery
Atlanta
Birmingham
Chattanooga
Nashville
Louisville
Cincinnati
Columbus
Indianapolis
Springfield
Peoria
Chicago
Milwaukee
Madison
Green Bay
Marquette
Duluth
Sault Ste Marie
Parry Sound
Toronto
Kingston
Ottawa
Montreal
Quebec
Father Point
Chatham
Halifax
Yarmouth
Sydney
Antigonish
Cochrane
Moosonee
Moosejaw

Chart VII. Isobars and Isotherms at Sea-level; Prevailing Winds, August, 1920.

Chart IX. Weather Map of North Atlantic Ocean, August 26, 1920.

Chart IX. Weather Map of North Atlantic Ocean, August 26, 1920.

(Plotted by F. A. Young.)

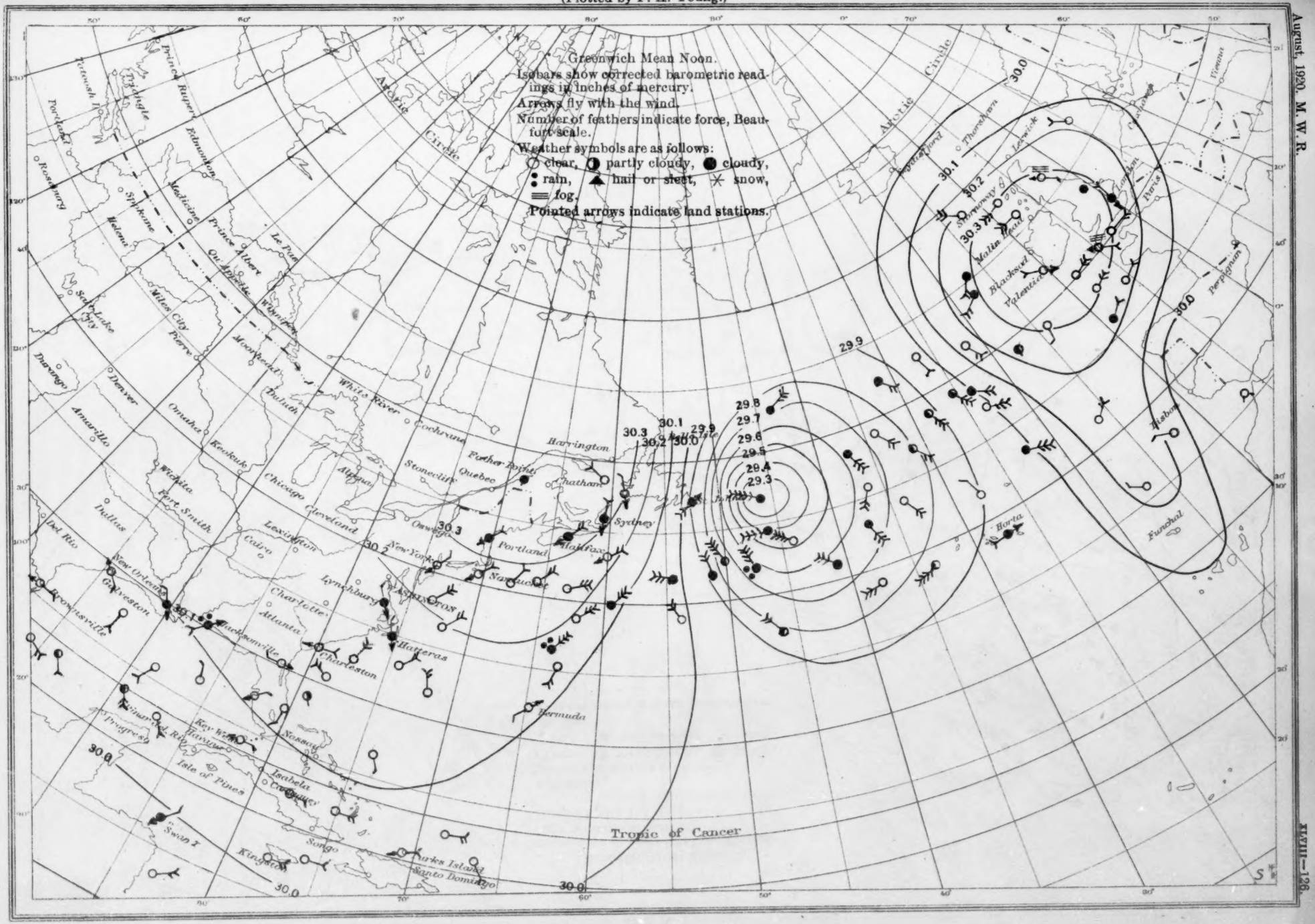
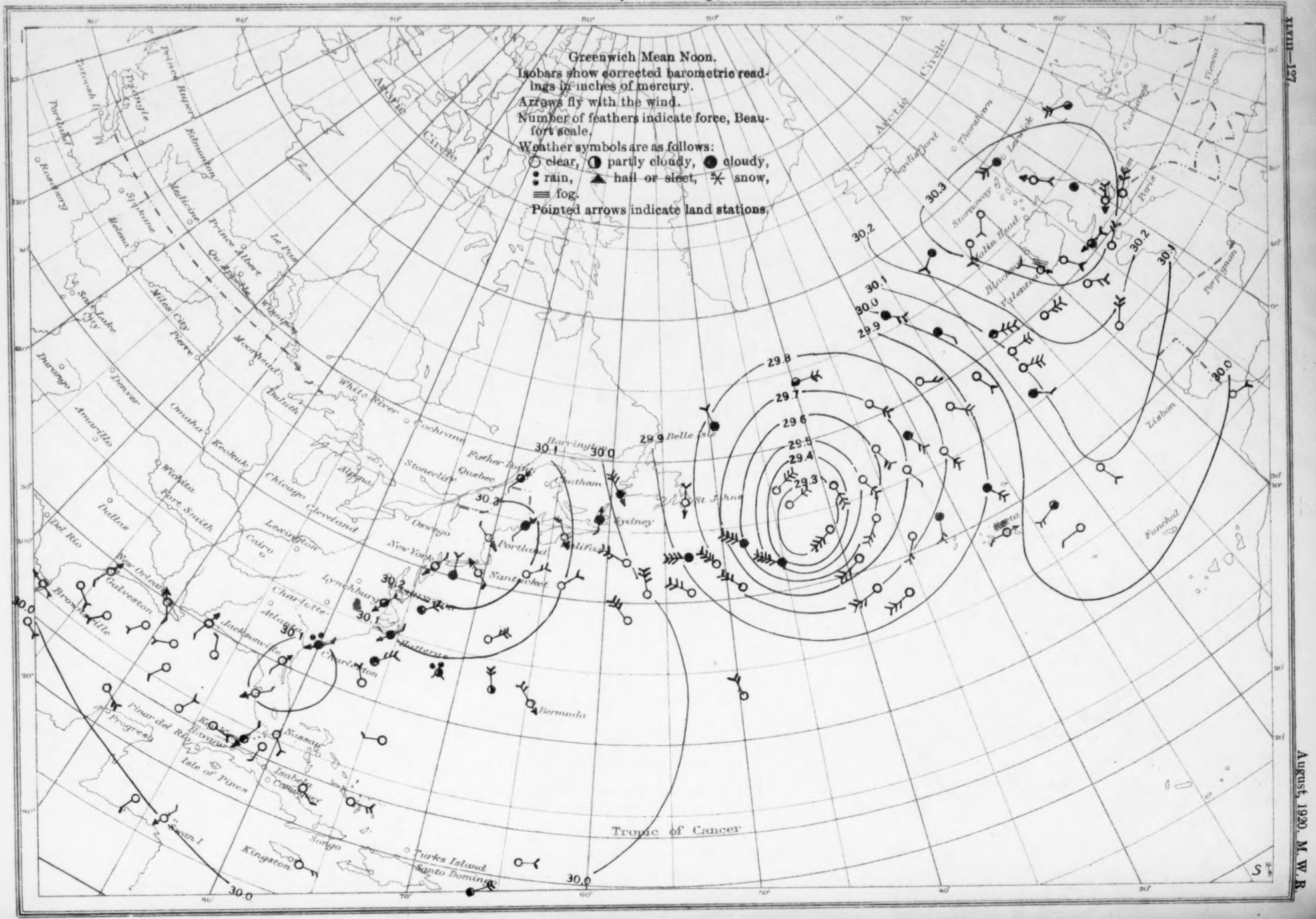
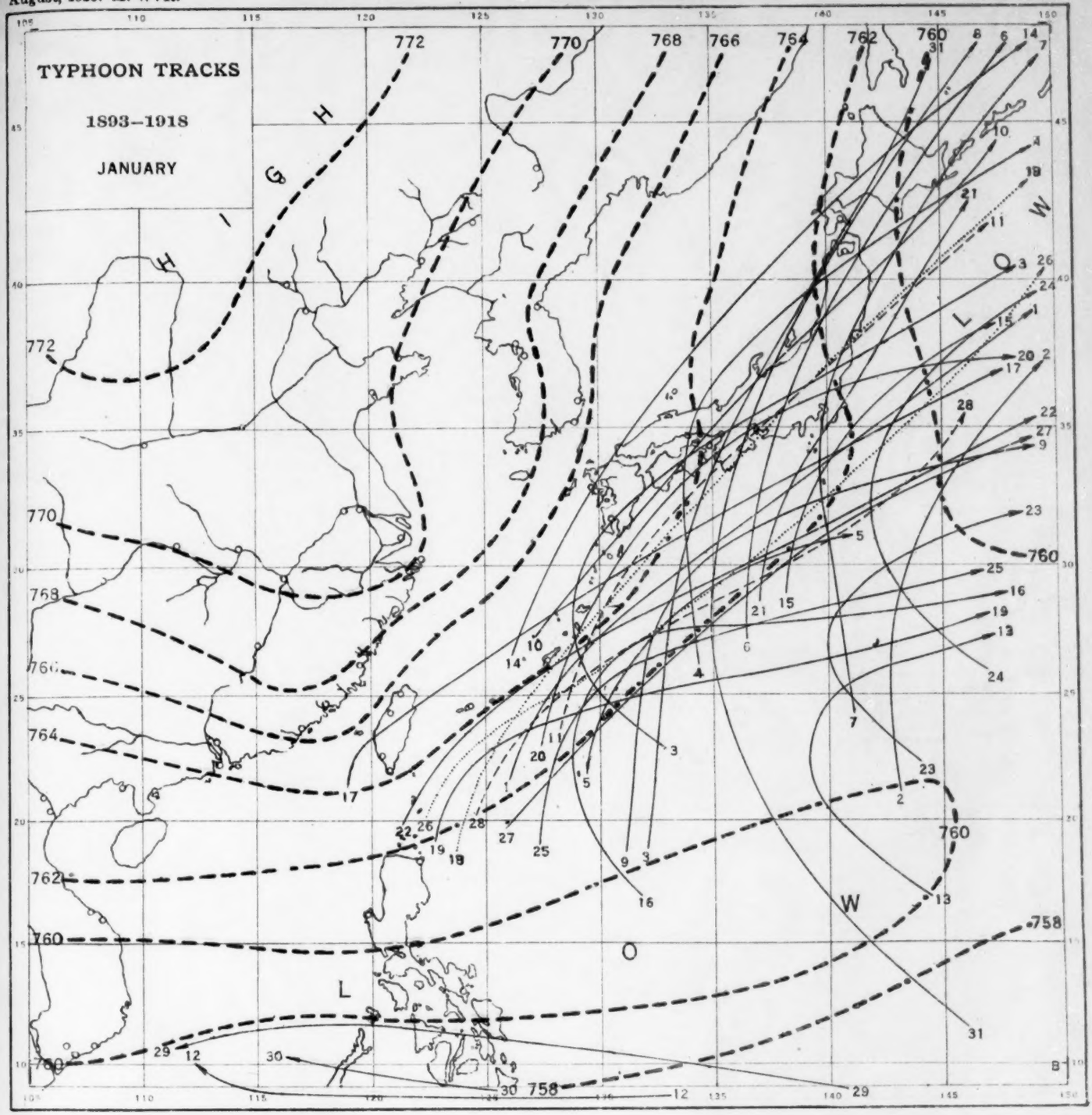


Chart X. Weather Map of North Atlantic Ocean, August 27, 1920.

(Plotted by F. A. Young.)





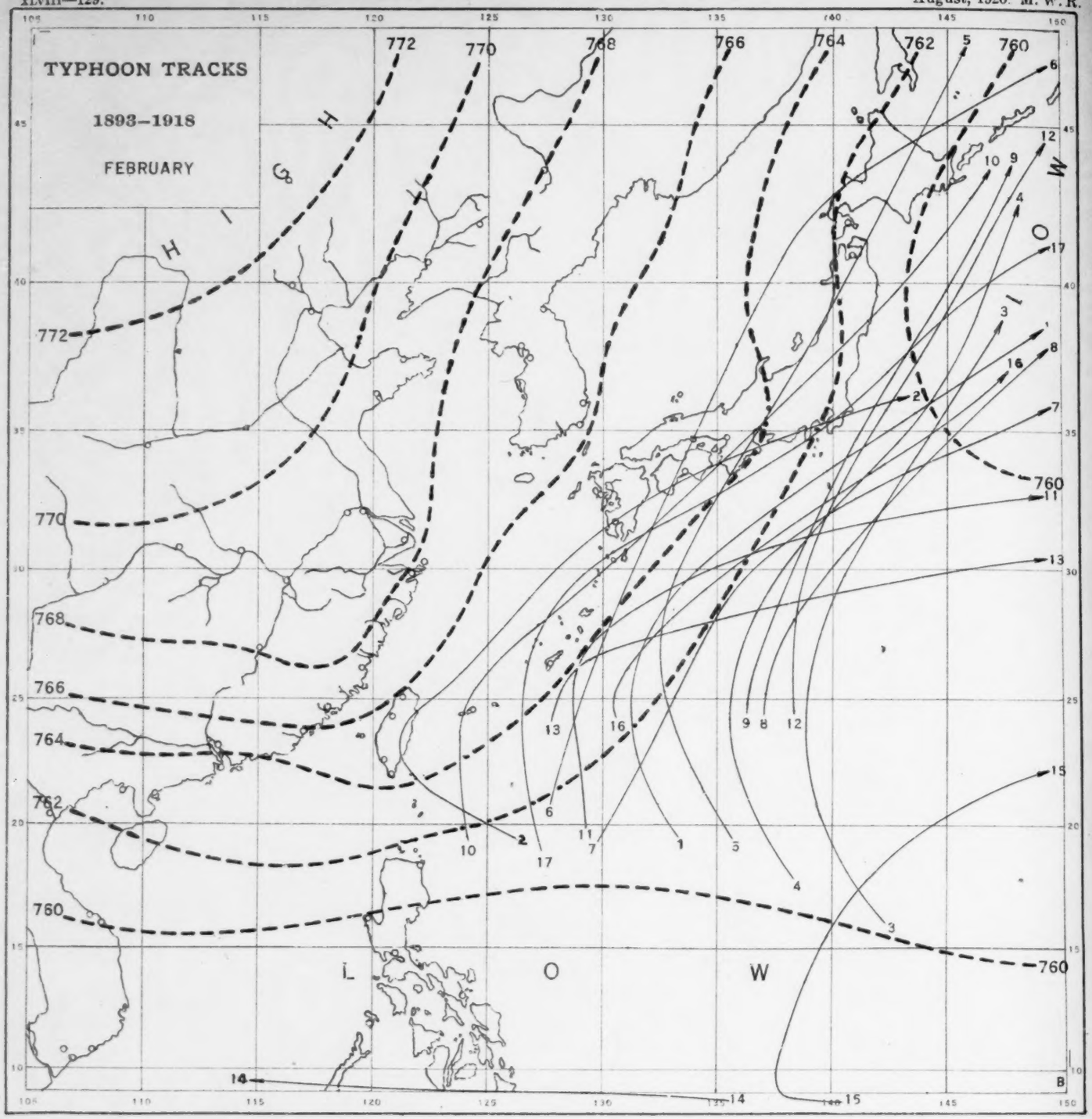
JANUARY.—*Single chart: 31 tracks; a little more than one every year.*

Remarks.—A diagonal traced on the map, from Cape St. James to La Pérouse Strait, divides it in two halves; the one perfectly free of storms, comprises the China Sea, the Eastern Sea, and the Sea of Japan; the other is the Pacific ploughed by the depressions. Four centres are seen on the edge of the Eastern Sea and near the W. coast of Nippon, but they form a rare exception. The very few ones who venture off the W. of Palawan, along the 10th parallel, are soon filled up before reaching the coast of the continent.

As regards their origin, there is a well marked focus between the Carolines and the Marianas, probably between lat. 5° and 8°, east of the 140th meridian; others take shape on the Pacific, off the N. of Luzon, but it is difficult to trace them up to the precise birth place. At first, they generally travel towards N. or NW., recurve to NE. between the 20th and the 25th parallels, the turning point is often found between the 130th meridian and Formosa. Most of the tracks are seen to pass between the Bonin group and Japan; some cross Nippon making for the Sea of Okhotsk; but the majority go away on the Pacific, where they frequently acquire a great violence, as shown by the reports of the ships sailing between the Far East and Vancouver or San Francisco.

[Reproduced from Atlas of the Tracks of 620 Typhoons, 1893–1918, by Louis Froc, S. J., Director Zi-ka-wei Observatory, Zi-ka-wei–Chang-hai, 1920.]

TYPHOONS IN THE FAR EAST DURING 26 YEARS.



FEBRUARY.—*Single chart: 17 tracks; a little more than two cases in three years.*

Remarks.—The line dividing the map in two areas, the one calm, the other disturbed, has advanced some 8 or 10 degrees towards the East. The Philippines, Formosa and Kiusiu are practically out of the dangerous zone; the Sea of Japan and the Eastern Sea have been visited, in their eastern border, only once or twice; the Pacific, east of Luzon, is also remarkably free, as well as the China Sea where only one depression ventured a few miles W. of Palawan.

The centre of origin remains at the low latitudes, but is considerably less fertile; many depressions are detected only after they have travelled a long distance, but their convergence continues to point to a spot between the Carolines and Marianas. After having advanced towards N. or NNW., all of them recurve at a higher latitude than last month, about the 25th parallel or between lat. 25° and 30°, off the eastern Loochoos. They are seen to run towards the NE., and disappear on the Pacific, between the Bonin Is. and the Kuriles, with the same increase of strength and deepening of the central minimum as during the preceding month.

[Reproduced from Atlas of the Tracks of 620 Typhoons, 1893–1918, by Louis Froc, S. J., Director Zi-ka-wei Observatory, Zi-ka-wei–Chang-hai, 1920.]